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TO

The Oxford Surgery

(Loose-Leaf)

NEW YORK
OXFORD UNIVERSITY PRESS
AMERICAN BRANCH 35 West 32nd St.
LONDON - TORONTO - MELBOURNE - BOMBAY

GENERAL INDEX TO AUTHORS

Oxford Loose-Leaf Surgery

Henry R. Andrews, F.R.C.P. London
  Preparation of the Patient for Gynecological Operations........Vol. V, 3
Astley P. C. Ashhurst, M.D. Philadelphia
  Fractures of the Ankle........Vol. I, 945
W. Wayne Babcock, F.A.C.S. Philadelphia
  Spinal Anæsthesia........Vol. I, 139
Donald C. Balfour, F.A.C.S. Rochester, Minn.
  Operations upon the Spleen........Vol. III, 205
Channing W. Barrett, F.A.C.S. Chicago
  Operative Treatment of Genital Fistulæ........Vol. V, 79
Arthur E. Barker, F.R.C.S. London
  Operations for Hernia........Vol. III, 3
W. Blair Bell, M.D., B.S. Liverpool
  Operations upon the Uterine Tubes........Vol. V, 239
Vilray P. Blair, F.A.C.S.. St. Louis
  Plastic Repair of Wounds of the Face and Jaws........Vol. V, 615
  Correction of Deformities of the Lower Jaw........Vol. II, 339
Sir John Bland-Sutton, F.R.C.S. London
  Operations for Non-Malignant Affections of the Uterus........Vol. V, 101
  Operations for Diseases of the Ovary........Vol. V, 207
  After-Treatment of Gynecological Operations........Vol. V, 11
Victor Bonney, F.R.C.S. London
  Operations for Malignant Diseases of the Uterus........Vol. V, 149
W. Rowley Bristow, F.R.C.S. London
  Treatment of Joint and Muscle Injuries........Vol. I, 831
C. H. Browning, M.D., Ch.B., M.B. London
  Antiseptics........Vol. I, 899
Frederic F. Burghard, F.R.C.S. London
  Amputations........Vol. I, 177
  Operations upon Arteries, Veins and Lymphatics........Vol. I, 377
  Operations upon Muscles, Tendons and Tendon Sheaths........Vol. I, 622
  Operations upon Non-Tuberculous Bones........Vol. I, 673
  Operations upon Non-Tuberculous Joints........Vol. II, 3
  Operations upon the Male Genital Organs........Vol. IV, 3
James T. Case, F.R.C.S. Chicago
  Localization and Extraction of Foreign Bodies........Vol. V, 451
G. Lenthal Cheatle, F.R.C.S., Surg. Gen'l. R. N. London
  Operations for Cancer of the Lips and Face........Vol. II, 287
Frederick J. Cotton, F.A.C.S. Boston
  Colles' Fractures........Vol. I, 975
George W. Crile, F.A.C.S., F.R.C.S. Cleveland
  Operations upon the Thyroid Gland........Vol. III, 229
Carey Culbertson, F.A.C.S. Chicago
  Operations upon the Vulva and Vagina........Vol. V, 43
Arthur H. Curtis, F.A.C.S. Chicago
  Operative Treatment of Retrodisplacements........Vol. V, 312
V. C. David, M.D. Chicago
  Rectal Surgery under Local Anæsthesia........Vol. I, 1019
Joseph B. De Lee, F.A.C.S. Chicago
  Obstetrical Operations........Vol. V, 333

F. Swinford Edwards, F.R.C.S. London
  Operations upon the Rectum and Anus........Vol. III, 81
C. H. Fagge, F.R.C.S. London
  Operations upon the Jaws........Vol. II, 301
  Operations upon the Oesophagus........Vol. II, 523
Palmer Findley, F.A.C.S. Omaha
  Surgical Treatment of Puerperal Infections........Vol. V, 387
Sir P. J. Freyer, M.D., M.C.H. London
  Operations for Vesical Calculus........Vol. III, 685
  Operations upon the Prostate........Vol. III, 719
H. D. Gillies, F.R.C.S. London
  Principles of Plastic Surgery........Vol. II, 443
Sir Rickman J. Godlee, F.R.C.S. London
  Operations upon the Thorax........Vol. IV, 121
W. Sampson Handley, F.R.C.S. London
  Malignant Diseases of the Breast........Vol. IV, 101
  Surgery of the Lymphatics........Vol. I, 537
W. Douglas Harmer, F.R.C.S. London
  Operations upon the Larynx and Trachea........Vol. IV, 513
M. L. Harris, F.A.C.S. Chicago
  Local Anæsthesia........Vol. I, 97
Gilbert Horrax, A.B., M.D. Boston
  Gunshot Wounds of the Skull and Brain........Vol. V, 581
Isabella C. Herb, M.D. Chicago
  General Anæsthesia........Vol. I, 33
Agatha Hodgins, R.N. Cleveland
  Nitrous Oxide-Oxygen Anæsthesia........Vol. I, 75
Sir Robert Jones, F.R.C.S. Liverpool
  Injuries to the Joints........Vol. I, 727
E. Starr Judd, M.D. Rochester, Minn.
  Gastrojejunal Ulcer........Vol. I, 1060
Allen B. Kanavel, F.A.C.S. Chicago
  Surgery of the Hypophysis........Vol. III, 438
Sumner L. Koch, M.D. Chicago
  Chlorine Antiseptics........Vol. I, 913
  Gunshot Wounds of the Joints........Vol. V, 491
Burton J. Lee, F.A.C.S. New York
  Wounds of the Abdomen........Vol. V, 709
F. P. Legg, F.R.C.S. London
  Plastic Surgery........Vol. II, 353
Dean Lewis, A.B., M.D. Chicago
  Operations upon Nerves........Vol. I, 563
Richard Lewisohn, F.A.C.S. New York
  Blood Transfusion, Citrate Method........Vol. I, 407
Frank W. Lynch, F.A.C.S. San Francisco
  Peritonization........Vol. V, 177
J. M. H. MacLeod, F.R.C.S. London
  Burns and Scalds........Vol. II, 438
Sir G. H. Makins, F.R.C.S. London
  Operations upon the Intestines........Vol. II, 651
R. D. Maxwell, F.R.C.S. London
  Operations for Ectopic Gestation........Vol. V, 257

M. S. Mayou, F.R.C.S. London
  Opthalmic Operations.......... Vol. IV, 195
Sir Berkeley Moynihan, F.R.C.S. London
  Operations upon the Stomach.......... Vol. II, 555
David Newman, M.D. Glasgow
  Operations upon the Kidneys and Ureters.......... Vol. III, 539
Robert B. Osgood, M.D. Boston
  Bursæ, Diagnosis and Treatment of their Surgical Lesions...... Vol. I, 995
Edmund Owen, F.R.C.S. London
  Operations upon the Lips, Face and Jaw.......... Vol. II, 259
Dunlop P. Penhallow, M.D. Boston
  Wounds of the Long Bones.......... Vol. V, 509
N. M. Percy, F.A.C.S. Chicago
  Blood Transfusion.......... Vol. I, 397
Reuben Peterson, F.A.C.S. Ann Arbor
  Operations for Inversion of the Uterus.......... Vol. V, 323
Eugene Pool, F.A.C.S. New York
  Early Treatment of Gunshot Wounds.......... Vol. V, 745
A. W. Mayo Robson, F.R.C.S. Leeds
  Operations upon the Bile Passages and Pancreas.......... Vol. III, 263
  Operations upon the Pancreas.......... Vol. III, 331
L. Bathe Rawling, F.R.C.S. London
  Operations upon the Skull and Brain.......... Vol. III, 355
Percy Sargent, F.R.C.S. London
  Aseptic Surgery.......... Vol. I, 3
Frank E. Simpson, M.D. Chicago
  Radium Therapy.......... Vol. V, 401
Sir Harold J. Stiles, F.R.C.S. Edinburgh
  Operations upon the Breast.......... Vol. IV, 61
  Operations for Tuberculous Diseases of the Lymphatic Glands.. Vol. III, 167
  Operations for Tubercular Affections of Bones and Joints...... Vol. II, 121
W. Thoburn, F.R.C.S. Manchester
  Operations upon the Spinal Cord.......... Vol. III, 461
James E. Thompson, F.A.C.S., F.R.C.S. Galveston
  Surgical Affections of the Thyroglossal Duct.......... Vol. III, 254
Sir St. Clair Thomson, F.R.C.S. London
  Operations upon the Nose and its Accessory Cavities.......... Vol. IV, 609
Hunter F. Tod, F.R.C.P. London
  Operations upon the Ear.......... Vol. IV, 329
Wilfred Trotter, F.R.C.S. London
  Operations upon the Pharynx.......... Vol. II, 502
J. W. T. Walker, F.R.C.S. London
  Cystoscopy.......... Vol. III, 523
  Operations upon the Urethra.......... Vol. III, 749
  Operations upon the Bladder.......... Vol. III, 615
Thomas J. Watkins, F.A.C.S. Chicago
  Operative Treatment of Cystocele, Uterine Prolapse and Laceration of the Perineum.......... Vol. V, 271
George E. Waugh, F.R.C.S. London
  Operations upon the Tonsil.......... Vol. II, 492
H. J. Waring, F.R.C.S. London
  Operations upon the Tongue.......... Vol. II, 455
J. L. Yates, F.A.C.S. Milwaukee
  Wounds of the Thorax.......... Vol. V, 655

GENERAL SYNOPTICAL INDEX TO SUBJECTS

Oxford Loose-Leaf Surgery

Abdomen, Wounds of.......... (Lee) Vol. V, 709
Abdominal Aorta, Ligature of.......... Vol. I, 469
Abcess, Extra-Dural, Operations for.......... Vol. IV, 460
Acessory Nasal Sinuses, Operations upon.......... Vol. IV, 667
Acute Sprains.......... Vol. I, 842
Adhesions, Prevention of.......... Vol. V, 177
Adenoids, Removal of.......... Vol. IV, 706
After-Treatment of Nerve Injuries.......... Vol. I, 868
After-Treatment of Abdominal Operations.......... Vol. V, 11
After-Treatment of Fractures.......... Vol. I, 862
After-Treament of Gynecological Operations.......... Vol. V, 11
Amputations.......... (Burghard) Vol. I, 177
Amputations at the Ankle.......... Vol. I, 306
Amputations at Elbow.......... Vol. I, 248
Amputations of the Fingers.......... Vol. I, 213
Amputations of the Foot.......... Vol. I, 282
Amputations through the Forearm.......... Vol. I, 240
Amputations of the Hand.......... Vol. I, 213
Amputations at the Hip.......... Vol. I, 362
Amputations, Interscopulo-Thoracic.......... Vol. I, 270
Amputations through the Leg.......... Vol. I, 320
Amputations of the Lower Extremity.......... Vol. I, 275
Amputations at the Shoulder.......... Vol. I, 263
Amputations through the Thigh.......... Vol. I, 356
Amputations of the Toes.......... Vol. I, 275
Amputations, Trans-Calcaneal.......... Vol. I, 313
Amputations, Supra-Condyloid.......... Vol. I, 348
Amputations, Trans-Condyloid.......... Vol. I, 348
Amputations through the Upper Arm.......... Vol. I, 256
Amputations of the Upper Extremity.......... Vol. I, 213
Amputations at the Wrist.......... Vol. I, 223
Anæsthesia, General.......... (Herb) Vol. I, 33
Anæsthesia, Local.......... (Harris) Vol. I, 97
Anæsthesia, Local in Rectal Surgery.......... (David) Vol. I, 1019
Anæsthesia, Nitrous Oxide-Oxygen.......... (Hodgins) Vol. I, 75
Anæsthesia, Spinal.......... (Babcock) Vol. I, 139
Aneurysmal Varix, Operations for.......... Vol. I, 395
Ankle, Fractures of.......... (Ashhurst) Vol. I, 945
Ankle-Joint, Operations upon.......... Vol. II, 45
Ankle, Operaitons upon Tuberculous.......... Vol. II, 204
Ankle-Joint, Disarticulation at.......... Vol. I, 306
Antiseptics.......... (Browning) Vol. I, 899
Antiseptics, Carrel-Dakin Treatment.......... Vol. I, 913
Antiseptics, Chlorine.......... (Koch) Vol. I, 913
Appendectomy.......... Vol. II, 780
Arteries, Ligation of.......... Vol. I, 414
Arteriorrhaphy.......... Vol. I, 377

Aseptic Surgery (Sargent) Vol. I, 3
Bladder, Operations upon (Walker) Vol. III, 615
Bladder, Operations upon, in the Female Vol. III, 660
Blood Transfusion (Percy) Vol. I, 397
Blood Transfusion, Citrate Method (Lewisohn) Vol. I, 407
Bones, Non-Tuberculous, Operations upon (Burghard) Vol. I, 673
Bones and Joints, Tuberculous (Stiles) Vol. II, 121
Bones, Wounds of the Long (Penhallow) Vol. V, 509
Brain, Operations upon (Rawling) Vol. III, 363
Breast, Malignant Diseases of (Handley) Vol. IV, 101
Breast, Operations upon (Stiles) Vol. IV, 61
Bronchoscopy Vol. IV, 598
Burns and Scalds (MacLeod) Vol. II, 438
Bursæ Diagnosis and Treatment of their Surgical Lesions (Osgood) Vol. I, 995
Bursæ, Operations upon (Burghard) Vol. I, 668
Bursæ, Operations upon (Osgood) Vol. I, 995
Cæsarean Section (De Lee) Vol. V, 333
Carrel-Dakin Treatment of Infected Wounds Vol. I, 913
Cephaloceles, Operations for Vol. III, 455
Cheek, Plastic Operations upon Vol. II, 404
Chest, Injuries of Vol. IV, 121
Chest, Operations upon Vol. IV, 121
Chlorine Antiseptics (Koch) Vol. I, 913
Chronic Sprains, Treatment of Vol. I, 851
Cicatricial Deformities of the Fingers Vol. II, 431
Cleft Palate, Operations for Vol. II, 271
Colles' Fracture, Treatment of (Cotton) Vol. I, 975
Complications of Gynecological Operations Vol. V, 13
Contraction of the Fingers, Operations for Vol. II, 424
Cranio-Cerebral Operations (Rawling) Vol. III, 384
Cystocele, Operative Treatment of (Watkins) Vol. V, 271
Cystoscopy (Walker) Vol. III, 523
Cystotomy, Perineal Vol. III, 615
Cystotomy, Suprapubic Vol. III, 618
Deformities of the Lower Jaw (Blair) Vol. II, 339
Deformities, Operations for Vol. II, 418
Disarticulation at the Ankle-Joint Vol. I, 306
Disarticulation at the Elbow-Joint Vol. I, 248
Disarticulation at the Hip-Joint Vol. I, 362
Disarticulation at the Knee-Joint Vol. I, 342
Disarticulation at the Shoulder-Joint Vol. I, 263
Disarticulation at the Wrist-Joint Vol. I, 223
Ear, Operations upon (Tod) Vol. IV, 339
Early Treatment of Gunshot Wounds (Pool) Vol. V, 745
Ectopic Gestation, Operations for (Maxwell) Vol. V, 257
Elbow, Disarticulation at Vol. I, 248
Elbow-Joint, Operations upon Vol. II, 13
Elbow-Joint, Tuberculous, Operations upon Vol. II, 189
Endo-Aneurysmorrhaphy Vol. I, 382
Eustachean Tube, Operations upon Vol. IV, 388
Extra-Dural Abscess, Operations for Vol. IV, 460
Extra-Uterine Pregnancy, Operations for Vol. V, 257
Eye, Operations upon (Mayou) Vol. IV, 195
Face and Jaws, Wounds of (Blair) Vol. V, 615
Face, Plastic Operations upon Vol. II, 391

Fingers, Amputations of.......Vol. I, 213
Fingers, Contractions of, Operations for.......Vol. II, 424
Foot, Amputations of.......Vol. I, 282
Foot, Ligature of Arteries of.......Vol. I, 423
Foot, Tuberculous, Operations upon.......Vol. II, 200
Forearm, Amputation through.......Vol. I, 240
Forearm, Ligature of Arteries of.......Vol. I, 474
Foreign Bodies, Localization and Extraction of.......(Case) Vol. V, 451
Fractures, Operations upon.......Vol. I, 699
Fractures, Treatment of.......(Penhallow) Vol. V, 509
Fractures, Early Treatment of.......(Pool) Vol. V, 751
Fractures, Colles' Treatment of.......(Cotton) Vol. I, 975
Fractures of the Ankle.......(Ashhurst) Vol. I, 945
Fractures of the Skull, Operations for.......Vol. III, 384
Fractures of the Wrist.......(Cotton) Vol. I, 975
Fractures, After-Treatment of.......Vol. I, 862
Gall-Bladder, Anatomical Considerations.......Vol. III, 263
Gall-Bladder, Operations upon.......(Robson) Vol. III, 285
Gastro-Jejunal Ulcer, Treatment of.......(Judd) Vol. I, 1060
General Anæsthesia.......(Herb) Vol. I, 33
Genital Fistulæ, Operative Treatment of.......(Barrett) Vol. V, 79
Graduated Contraction in Muscle and Joint Injuries.......Vol. I, 831
Gall-Stones, Operations for.......(Robson) Vol. III, 273
Gunshot Wounds, Early Treatment of.......(Pool) Vol. V, 745
Gunshot Wounds of the Abdomen.......(Lee) Vol. V, 709
Gunshot Wounds of the Joints.......(Koch) Vol. V, 491
Gunshot Wounds of the Skull and Brain.......(Horrax) Vol. V, 581
Gunshot Wounds of the Thorax.......(Yates) Vol. V, 665
Gynecological Operations, Preparation of the Patient for. (Andrews) Vol. V, 3
Gynecological Operations, After-Treatment, Risks and Sequelæ (Bland-Sutton).......Vol. V, 11
Gynecological Operations, Complications of.......Vol. V, 13
Hæmorrhoids, Operations for.......Vol. III, 113
Hammer Toe, Operations for.......Vol. II, 435
Hand, Amputation of.......Vol. I, 213
Hand, Ligature of Arteries of.......Vol. I, 474
Hare-Lip, Operations for.......Vol. II, 259
Heart, Operations upon.......Vol. IV, 171
Hernia, Operations for.......(Barker) Vol. III, 3
Hernia, Radical Cure in General.......Vol. III, 3
Hernia, Diaphragmatic, Non-Strangulated.......Vol. III, 19
Hernia, Epigastric, Non-Strangulated.......Vol. III, 11
Hernia, Non-Strangulated Femoral, Operations for.......Vol. III, 44
Hernia, Non-Strangulated Femoral, Seelig's Operation for.......Vol. III, 46
Hernia, Non-Strangulated Inguinal, Andrews' Operation for.......Vol. III, 39
Hernia, Non-Strangulated Inguinal, Barker's Operation for.......Vol. III, 25
Hernia, Non-Strangulated Inguinal, Bassini's Operation for.......Vol. III, 29
Hernia, Non-Strangulated Inguinal, Halsted's Operation for.......Vol. III, 24
Hernia, Non-Strangulated Inguinal, Kocher's Operation for.......Vol. III, 26
Hernia, Non-Strangulated Inguinal, Transplantation of Facia Lata..Vol. III, 41
Hernia, Non-Strangulated Inguinal, Operation in the Female.......Vol. III, 42
Hernia, Strangulated, General Considerations.......Vol. III, 52
Hernia, Strangulated, Preparation of the Patient.......Vol. III, 57
Hernia, Strangulated Diaphragmatic, Operations for.......Vol. III, 77
Hernia, Strangulated Femoral, Operations for.......Vol. III, 73

Hernia, Strangulated Inguinal, Operations for .... Vol. III, 60
Hernia, Strangulated Inguinal, Treatment of Suspected Bowel .... Vol. III, 62
Hernia, Strangulated Obturator, Operations for .... Vol. III, 77
Hernia, Strangulated Umbilical, Operations for .... Vol. III, 76
Hernia, Strangulated Ventral, Operations for .... Vol. III, 76
Hernia, Umbilical, Non-Strangulated .... Vol. III, 12
Hernia, Ventral, Non-Strangulated .... Vol. III, 18
Hip-Joint, Operations upon .... Vol. II, 92
Hip-Joint, Disarticulation at .... Vol. I, 362
Hip-Joint, Operation upon Tubercular .... Vol. II, 232
Hydrocephalus, Internus, Operations for .... Vol. III, 452
Hypophysis, Surgery of .... (Kanavel) Vol. III 438
Infected Wounds, Carrel-Dakin Treatment of .... Vol. I, 913
Injuries to Joints .... (Jones) Vol. I, 727
Interscapulo-Thoracic Amputations .... Vol. I, 270
Intestines, Operations upon .... (Makins) Vol. II, 651
Intracranial Abscess, Operations for .... Vol. IV, 497
Intubation of the Larynx .... Vol. IV, 588
Inversions of the Uterus, Operations for .... (Peterson) Vol. V, 323
Jaw, Upper, Operations upon .... Vol. II, 301
Jaw, Lower, Operations upon .... Vol. II, 318
Joints, Injuries to .... (Jones) Vol. I, 727
Joints, Gunshot Wounds of .... (Koch) Vol. V, 491
Joint and Muscle Injuries .... (Bristow) Vol. I, 881
Joints, Non-Tuberculous Affections of .... (Burghard) Vol. II, 3
Joints, Tuberculous Affections of .... (Stiles) Vol. II, 179
Kidney and Ureters, Regional Anatomy of .... Vol. III, 539
Kidney and Ureters, Operations upon .... (Newman) Vol. III, 548
Knee, Amputations at .... Vol. I, 342
Knee-Joint, Operations upon .... Vol. II, 56
Knee-Joint, Operations upon Tuberculous .... Vol. II, 215
Knee-Joint, Disarticulation at .... Vol. I, 342
Knee, Ligature of Arteries of .... Vol. I, 436
Labyrinth, Operations upon .... Vol. IV, 443
Lacerations of the Perineum, Operative Treatment of .... Vol. V, 271
Laminectomy .... Vol. III, 469
Larynx, Operations upon .... Vol. IV, 513
Larynx, Intubation of .... Vol. IV, 588
Leg, Amputations through .... Vol. I, 320
Leg, Ligature of Arteries of .... Vol. I, 425
Ligature of Arteries .... Vol. I, 414
Ligature of Arteries of the Upper Extremity .... Vol. I, 474
Ligature of Arteries of the Hand .... Vol. I, 474
Ligature of Arteries of the Forearm .... Vol. I, 474
Ligature of Arteries of Upper Arm and Axilla .... Vol. I, 484
Ligature of Arteries of the Neck .... Vol. I, 495
Ligature of Arteries of the Pelvis .... Vol. I, 454
Ligature of the Abdominal Aorta .... Vol. I, 469
Ligature of Arteries of the Lower Extremity .... Vol. I, 413
Ligature of Arteries of the Thigh .... Vol. I, 437
Ligature of Arteries of the Knee .... Vol. I, 436
Ligature of Arteries of the Leg .... Vol. I, 425
Ligature of Arteries of the Foot .... Vol. I, 423
Lips, Plastic Operations upon .... Vol. II, 391
Lips, Face and Jaw, Operations for Cancer of .... Vol. II, 287

Local Anæsthesia..(Harris) Vol. I, 97
Local Anæsthesia in Rectal Surgery....................(David) Vol. I, 1019
Localization and Extraction of Foreign Bodies............(Case) Vol. V, 451
Long Bones, Wounds of..........................(Penhallow) Vol. V, 509
Lower Extremity, Amputations of..................................Vol. I, 275
Lower Extremity, Ligature of Arteries of.........................Vol. I, 413
Lower Jaw, Correction of Deformities of.........................Vol. II, 339
Lower Jaw, Operations upon.......................................Vol. II, 318
Lungs, Operations upon..Vol. IV, 158
Lymphatics, Surgery of..............................(Handley) Vol. I, 537
Lymphatic Glands, Operations upon Tuberculous.................Vol. III, 167
Malignant Diseases of the Uterus, Operations for.....(Bonney) Vol. V, 149
Mastoid Process, Operations upon................................Vol. IV, 398
Menengitis of Ototic Origin, Operations for.....................Vol. IV, 464
Mouth, Plastic Operations upon..................................Vol. II, 391
Muscles, Operations upon...Vol. I, 623
Nasal Growth, Operations for Removal of.........................Vol. IV, 654
Nasal Septum, Operations for Deformities of.....................Vol. IV, 637
Neck, Ligature of Arteries of....................................Vol. I, 495
Nerves, Operations upon.............................(Lewis) Vol. I, 563
Nerve Injuries, After-Treatment of...............................Vol. I, 868
Nitrous Oxide-Oxygen, Anæsthesia....................(Hodgins) Vol. I, 75
Non-Malignant Affections of the Uterus, Operations for (Bland-Sutton) ....Vol. V, 101
Non-Tuberculous Bones, Operations upon...........................Vol. I, 673
Non-Tuberculous Affections of Joints.............................Vol. II, 3
Nose, Operations upon..............................(Thomson) Vol. IV, 609
Obstetrical Operations.............................(De Lee) Vol. V, 333
Oesophagus, Operations upon.........................(Fagge) Vol. II, 523
Operations upon the Nasal Accessory Sinuses...........(Tod) Vol. IV, 667
Operations for Aneurysmal Varix..................................Vol. I, 395
Operations upon the Ankle-Joint..................................Vol. II, 45
Operations upon Arteries, Veins and Lymphatics......(Burghard) Vol. I, 377
Operations upon the Bile Passages and Pancreas.......(Robson) Vol. III, 363
Operations upon the Bladder..........................(Walker) Vol. III, 615
Operations upon the Breast...........................(Stiles) Vol. IV, 61
Operations upon Bursæ..............................(Burghard) Vol. I, 668
Operations upon Bursæ...............................(Osgood) Vol. I, 995
Operations for Cancer of the Lips and Face...........(Cheatle) Vol. II, 287
Operations upon the Chest.......................................Vol. IV, 121
Operations for Cleft-Palate.....................................Vol. II, 271
Operations for Deformities......................................Vol. II, 418
Operations for Deformities of the Fingers.......................Vol. II, 431
Operations upon the Ear................................(Tod) Vol. IV, 329
Operations for Ectopic Gestation....................(Maxwell) Vol. V, 257
Operations upon the Elbow-Joint..................................Vol. II, 13
Operations for Extra-Uterine Pregnancy...........................Vol. V, 257
Operations upon the Eye..............................(Mayou) Vol. IV, 195
Operations for Contraction of Fingers...........................Vol. II, 424
Operations upon Fractures..Vol. I, 699
Operations upon the Gall-Bladder....................(Robson) Vol. III, 285
Operations for Gall-Stones..........................(Robson) Vol. III, 273
Operations upon the Male Genital Organs............(Burghard) Vol. IV, 3
Operations for Hammer Toe.......................................Vol. II, 435
Operations for Hare-Lip...Vol. II, 259

Operations upon the Heart........Vol. IV, 171
Operations for Hernia........(Barker) Vol. III, 3
Operation for Hæmorrhoids........(Edwards) Vol. III, 113
Operations upon the Hip-Joint........Vol. II, 92
Operations upon the Intestines........(Makins) Vol. II, 651
Operations for Intracranial Abscess........Vol. IV, 497
Operations upon the Jaws........(Fagge) Vol. II, 301
Operations upon the Kidney and Ureters........(Newman) Vol. III, 539
Operations upon the Knee-Joint........Vol. II, 56
Operations upon the Larynx........(Harmer) Vol. IV, 513
Operations upon the Lips, Face and Jaw........(Owen) Vol. II, 259
Operations upon the Lower Jaw........Vol. II, 318
Operations upon the Lungs........Vol. IV, 158
Operations forMalignant Diseases of the Uterus........(Bonney) Vol. V, 149
Operations for Menengitis of Ototic Origin........Vol. IV, 464
Operations upon Muscles, Tendons, Sheaths and Bursæ (Burghard) Vol. I, 623
Operations upon Nerves........(Lewis) Vol. I, 563
Operations for Non-Malignant Affections of the Uterus (Bland-Sutton)........Vol. V, 101
Operations upon Non-Tuberculous Bones........(Burghard) Vol. I, 673
Operations upon Non-Tuberculous Joints........(Burghard) Vol. II, 3
Operations upon the Nose........(Thomson) Vol. IV, 609
Operations upon the Oesophagus........(Fagge) Vol. II, 523
Operations for Diseases of the Ovary........(Bland-Sutton) Vol. V, 207
Operations upon the Pancreas........(Robson) Vol. III 331
Operations upon the Penis........Vol. IV, 3
Operations upon the Pericardium........Vol. IV, 171
Operations for Pharyngeal Abscess........Vol. II, 499
Operations upon the Pharynx........(Trotter) Vol. II, 502
Operations upon the Prostate........(Freyer) Vol. III, 719
Operations upon the Pulmonary Artery........Vol. IV, 181
Operations upon the Rectum and Anus........(Edwards) Vol. III, 81
Operations upon the Scrotum and Cord........Vol. IV, 30
Operations upon the Seminal Vesicles........Vol. IV, 51
Operations upon the Shoulder-Joint........Vol. II, 28
Operations upon the Skull and Brain........(Rawling) Vol. III, 355
Operations upon the Spinal Cord........(Thoburn) Vol. III, 461
Operations upon the Spleen........(Balfour) Vol. III, 205
Operations upon the Stomach........(Moynihan) Vol. II, 555
Operations for Supernumerary Digits........Vol. II, 423
Operations upon Tarsal Bones and Joints........Vol. II, 50
Operations upon the Temporo-Maxillary Joint........Vol. II, 331
Operations upon Tendons........Vol. I, 629
Operations upon Tendon Sheaths........Vol. I, 666
Operations upon the Testicles........Vol. IV, 38
Operations upon the Thorax........(Godlee) Vol. IV, 121
Operations upon the Thyroid Gland........(Crile) Vol. III, 229
Operations upon the Thyroglossal Duct........(Thompson) Vol. III, 251
Operations upon the Tongue........(Waring) Vol. II, 455
Operations upon the Tonsils........(Waugh) Vol. II, 492
Operations upon the Trachea........(Harmer) Vol. IV, 556
Operations upon Tuberculous Long-Bones........Vol. II, 121
Operations upon Tuberculous Short-Bones........Vol. II, 151
Operations upon Tubercular Bones of the Vault and Skull........Vol. II, 155
Operations upon Tuberculous Ankle-Joint........Vol. II, 204

Operations upon Tuberculous Bones and Joints..........(Stiles) Vol. II, 121
Operations upon Tuberculous Elbow-Joint..........................Vol. II, 189
Operations upon Tuberculous Foot..........................Vol. II, 200
Operations upon Tuberculous Hip-Joint..........................Vol. II, 232
Operations upon Tuberculous Knee-Joint..........................Vol. II, 215
Operations upon Tuberculous Lymphatic Glands........(Stiles) Vol. III, 167
Operations upon Tuberculous Ribs..........................Vol. II, 173
Operations upon Tuberculous Sacro-Iliac Joints..........................Vol. II, 255
Operations upon Tuberculous Shoulder-Joint..........................Vol. II, 197
Operations upon Tuberculous Spine..........................Vol. II, 160
Operations upon Tuberculous Wrist-Joint..........................Vol. II, 179
Operations upon the Upper Jaw..........................Vol. II, 301
Operations upon the Urethra..........................(Walker) Vol. III, 749
Operations upon the Uterine Tubes..........................(Bell) Vol. V, 239
Operations for Inversion of the Uterus..............(Peterson) Vol. V, 323
Operations for Varicose Aneurysm..........................Vol. I, 396
Operations upon the Vas Deferens..........................Vol. IV, 35
Operations upon Veins..........................Vol. I, 527
Operations upon the Vermiform Appendix............(Makins) Vol. III, 780
Operations for Vesical Calculus..........................(Freyer) Vol. III, 685
Operations upon the Vulva and Vagina.............(Culbertson) Vol. V, 43
Operations for Webbed Fingers..........................Vol. II, 418
Operations upon the Wrist-Joint..........................Vol. II, 9
Operative Treatment of Cystocele....................(Watkins) Vol. V, 271
Operative Treatment of Genital-Fistulæ..................(Barrett) Vol. V, 79
Operative Treatment of Retrodisplacements............(Curtis) Vol. V, 312
Opthalmic Operations..........................(Mayou) Vol. IV, 195
Ovary, Operations for Diseases of..............(Bland-Sutton) Vol. V, 207
Palate, Plastic Operations upon..........................Vol. II, 416
Pancreas, Operations upon..........................(Robson) Vol. III, 331
Pelvis, Ligature of Arteries of..........................Vol. I, 454
Penis, Operations upon..........................Vol. IV, 3
Pericardium, Operations upon..........................Vol. IV, 171
Pereneorrhaphy..........................(Watkins) Vol. V, 292
Peritonization..........................(Lynch) Vol. V, 177
Pharyngeal Abscess, Operations for..........................Vol. II, 499
Pharynx, Operations upon..........................Vol. II, 502
Plastic Surgery..........................(Legg) Vol. II, 353
Plastic Surgery, Principles of..........................(Gillies) Vol. II, 443
Plastic Operations upon the Lips, Face and Mouth.................Vol. II, 391
Plastic Operations upon the Palate..........................Vol. II, 416
Potts Fracture..........................(Ashhurst) Vol. I, 945
Preparation of the Patient for Gynecological Operations..(Andrews) Vol. V, 3
Prostate, Operations upon..........................(Freyer) Vol. III, 719
Puerperal Infections, Surgical Treatment..............(Findley) Vol. V, 387
Pulmonary Artery, Operations upon..........................Vol. IV, 181
Radium Therapy..........................(Simpson) Vol. V, 401
Rectal Surgery, under Local Anæsthesia................(David) Vol. I, 1019
Rectum and Anus, Operations upon..................(Andrews) Vol. III, 86
Rectum and Anus, Methods of Examination..........................Vol. III, 81
Rectum and Anus, Operations for Fistulæ in Ano..................Vol. III, 96
Rectum and Anus, Operations for Rectal Fistulæ..................Vol. III, 105
Rectum and Anus, Removal of Polypi..........................Vol. III, 106
Rectum and Anus, Excision of Tuberculous Membrane............Vol. III, 107
Rectum and Anus, Operation for Prolapse..........................Vol. III, 108

Rectum and Anus, Operations for Hæmorrhoids ... Vol. III, 113
Rectum, Excision of ... Vol. III, 131
Rectum, Operations for Stricture of ... Vol. III, 159
Retrodisplacements, Operative Treatment of ... (Curtis) Vol. V, 312
Rhinoplasty ... Vol. II, 373
Ribs, Operations upon Tubercular ... Vol. II, 173
Sacro-Iliac Joints, Operations upon ... Vol. II, 255
Scrotum and Cord, Operations upon ... Vol. IV, 30
Seminal Vesicles, Operations upon ... Vol. IV, 51
Shock, Complications of ... (Moynihan) Vol. II, 643
Short Long-Bones, Operations upon Tubercular ... Vol. II, 151
Shoulder-Joint, Operations upon ... Vol. II, 283
Shoulder-Joint, Disarticulation at ... Vol. I, 263
Shoulder-Joint, Operations upon Tuberculous ... Vol. II, 197
Skin Grafting ... (Legg) Vol. II, 353
Skull and Brain, Operations upon ... (Rawling) Vol. III, 355
Skull and Brain, Special Technique of Operations ... Vol. III, 363
Skull and Brain, Gunshot Wounds of ... (Horrax) Vol. V, 581
Skull, Fracture of, Operation for ... Vol. III, 384
Sodium Citrate, in Blood Transfusion ... Vol. I, 407
Spina Bifida, Operations for ... Vol. III, 461
Spinal Anæsthesia ... (Babcock) Vol. I, 139
Spine, Operations upon Tuberculous ... Vol. II, 160
Spleen, Operations upon ... (Balfour) Vol. III, 205
Sprains, Acute, Treatment of ... Vol. I, 842
Sprains, Chronic, Treatment of ... Vol. I, 851
Stomach, Operations upon ... (Moynihan) Vol. II, 555
Supra-Condyloid Amputations ... Vol. I, 348
Surgical Treatment of Puerperal Infections ... (Findley) Vol. V, 387
Supernumerary Digits, Operations for ... Vol. II, 423
Tarsal Bones and Joints, Operations upon ... Vol. II, 50
Temporo-Maxillary Joint, Operations upon ... Vol. II, 331
Tendons, Operations upon ... Vol. I, 629
Tendon Sheaths, Operations upon ... Vol. I, 666
Testicles, Operations upon ... Vol. IV, 38
Thigh, Amputations through ... Vol. I, 356
Thigh, Ligature of Arteries of ... Vol. I, 437
Thorax, Operations upon ... (Godlee) Vol. IV, 121
Thorax, Wounds of ... (Yates) Vol. V, 665
Thyroid Gland, Operations upon ... (Crile) Vol. III, 229
Thyroglossal Duct, Surgical Affections of ... (Thompson) Vol. III, 254
Toes, Amputation of ... Vol. I, 275
Tongue, Operations upon ... Vol. II, 455
Tonsils, Operations upon ... (Waugh) Vol. II, 492
Trachea, Operations upon ... (Harmer) Vol. IV, 556
Tracheoscopy ... Vol. IV, 598
Trans-Calcaneal Amputations ... Vol. I, 313
Trans-Condyloid Amputations ... Vol. I, 348
Transfusion of Blood ... (Percy) Vol. I, 397
Transfusion of Blood, Citrate Method ... (Lewisohn) Vol. I, 407
Trench Foot ... Vol. V, 773
Tubercular Long-Bones, Operations upon ... Vol. II, 121
Tubes, Uterine, Operations upon ... (Bell) Vol. V, 239
Ulcer, Gastro-Jejunal ... (Judd) Vol. I, 1060
Upper Arm, Amputations through ... Vol. I, 256

Upper Arm and Axilla, Ligature of Arteries of....................Vol. I, 484
Upper Extremity, Amputations of................................Vol. I, 213
Upper Extremity, Ligature of Arteries of........................Vol. I, 474
Upper Jaw, Operations upon....................................Vol. II, 301
Ureters, Operations upon......................................Vol. III, 604
Urethra, Operations upon..........................(Walker) Vol. III, 749
Uterine Tubes, Operations upon.........................(Bell) Vol. V, 239
Uterus, Non-Malignant Affections of............(Bland-Sutton) Vol. V, 101
Uterus, Operations for Malignant Diseases of.........(Bonney) Vol. V, 149
Varicose Aneurysm, Operations for..............................Vol. I, 396
Vas Deferens, Operations upon..................................Vol. IV, 35
Vault and Skull, Operations upon...............................Vol. II, 155
Veins, Operations upon...Vol. I, 527
Vermiform Appendix, Operations on..................(Makins) Vol. II, 780
Vesical Calculus, Operations for....................(Freyer) Vol. III, 685
Vesical Calculus, Operations for in the Female................Vol. III, 705
Vesico-Vaginal Fistulæ, Repair of.............................Vol. III, 676
Vulva and Vagina, Operations upon................(Culbertson) Vol. V, 43
Webbed Fingers, Operations for.................................Vol. II, 418
Wounds, Infected, Treatment of.................................Vol. I, 913
Wounds of the Abdomen..................................(Lee) Vol. V, 709
Wounds of the Face and Jaws...........................(Blair) Vol. V, 615
Wounds, Gunshot, Early Treatment of....................(Pool) Vol. V, 745
Wounds, Gunshot, of the Joints.........................(Koch) Vol. V, 491
Wounds, Gunshot, of the Skull and Brain..............(Horrax) Vol. V, 581
Wounds of the Long Bones.........................(Penhallow) Vol. V, 509
Wounds of the Thorax..................................(Yates) Vol.. V, 665
Wrist, Amputations at..Vol. I, 233
Wrist, Fractures of...................................(Cotton) Vol. I, 975
Wrist-Joint, Operations upon...................................Vol. II, 9
Wrist-Joint, Tubercular, Operations upon.......................Vol. II, 179

FRACTURES OF THE ANKLE

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Philadelphia

Anatomy and Physiology of the Ankle.*

The ankle-joint is formed by the tibiofibular mortise above and the trochlea of the astragalus below, the latter fitting into the mortise as a tenon. The trochlear surface is one-fourth wider in front than behind, conforming to the divergent direction of the inner surfaces of the malleoli. The inferior articular surface of the tibia may be described as the roof or ceiling (*plafond*) of the joint; and the articular surfaces of the malleoli have long been known as the "cheeks" of the mortise. That portion of the fibula which projects beyond the tibial plafond is properly called the external malleolus; and the corresponding projection of the tibia is called the internal malleolus. The posterior lip of the tibial plafond projects so low as to have been called by Destot (1911) the posterior malleolus. It serves as a posterior reinforcement of the mortise. This is further deepened by the transverse tibiofibular ligament, which extends from the external malleolus to the posterior lip of the tibia. Thus, in walking, as the foot meets the ground in plantar flexion, the leg bones are checked in their tendency to slide forward on the astragalus by the wedge shape of the trochlea of the latter bone (broad anteriorly and narrow posteriorly), by the corresponding divergence of the anteroposterior planes of the malleoli, and by the long posterior lip of the tibial plafond. In walking backward (always digitigrade, not plantigrade) the same mechanism is effective.

The fibula is attached firmly to the tibia, but a slight range of motion is permitted. The interosseous membrane extends throughout the length of the tibial and fibular shafts, the fibres running downward and later-

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* See Ashhurst and Bromer: Classification and Mechanism of Fractures of the Leg Bones involving the Ankle. (Trans. Am. Surg. Assoc. 1921. xxxix, 644.)

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ally from tibia to fibula (as in the forearm from radius to ulna); and in addition there are strong ligaments whose fibres run in the same direction, binding both ends of the fibula to the tibia at which points only are the two bones in contact. At the upper end, where the head of the fibula butts against the overhanging external condyle of the tibia, there is a synovial cavity in the tibiofibular joint; but at the lower end, where the fibula is received into a longitudinal groove between the anterior and posterior tubercles on the lateral surface of the tibia (Fig. 365), no such joint cavity exists, union being effected by a dense felt-like interosseous ligament, reinforced in front by the anterior inferior tibiofibular ligament, and behind by the posterior ligament of the same name.

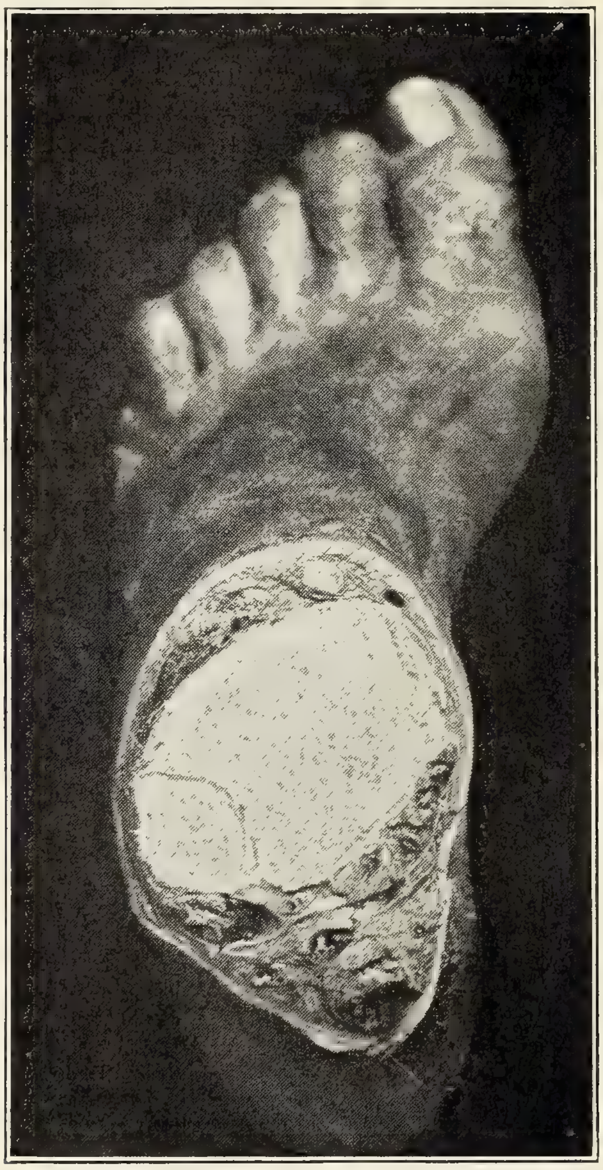

Fig. 365. Transverse Section of Leg Through Inferior Tibiofibular Joint, showing fibula lodged in its groove, formed by the anterior and posterior tubercles of the tibia. Note the obliquity of the intermalleolar axis, forming an angle of 30 degrees with the axis of motion of the ankle-joint, which is nearly transverse. Note that the anterior tubercle projects laterally much farther than the posterior, so that in anteroposterior roentgenograms its shadow much overlaps that of the fibula. (From a preparation in the laboratory of operative surgery, University of Pennsylvania.)

The malleoli, of which the external is the longer and posterior, serve to keep the foot (which is appended to the astragalus) under the leg bones. The astragalus has no muscles attached to it, and serves only as a ball in a ball-bearing joint to facilitate movements of the leg bones above and of the tarsal bones below and in front.

The foot is attached to the leg bones by ligaments. The lateral portions of these are the best developed, and they constitute for the ankle, as in other hinge joints, lateral bands which hinder motion except in the anteroposterior plane. The internal lateral ligament passes from the internal malleolus, radiating (1) anteriorly to the scaphoid and to the median surface of the calcaneum (sustentaculum tali) and (2) pos-

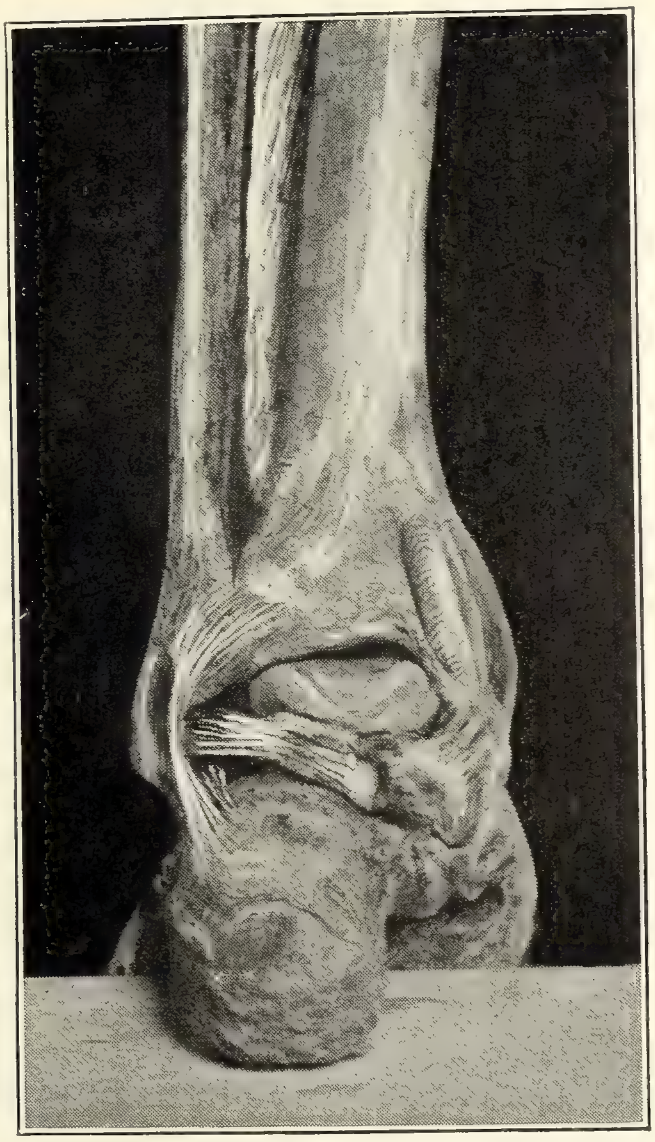

FIG. 366. POSTERIOR VIEW OF THE ANKLE-JOINT, all structures removed except the bandlike ligaments. Note the interosseous membrane, its fibers passing downward from the tibia to the fibula; the similarly directed fibers of the posterior inferior tibiofibular ligament; the middle band of the external lateral (fibulocalcanean) ligament; the posterior band of the external lateral ligament (fibuloastragalar ligament) attached to the lateral tubercle of the astragalus; the posterior fibers of the internal lateral ligament, and the posterior surface of the internal malleolus grooved for the tendon of the tibialis posticus. (From a preparation in the laboratory of operative surgery, University of Pennsylvania.)

teriorly to the median tubercle on the posterior surface of the astragalus. The external lateral ligament has three distinct bands, passing from the external malleolus: one goes forward to the lateral border of the neck of the astragalus, just above the sinus of the tarsus; another passes downward and slightly backward to the calcaneum; while the third, whose deep portion is extremely strong (Fig. 366), is attached to the lateral tubercle on the posterior surface of the astragalus (os trigonum),

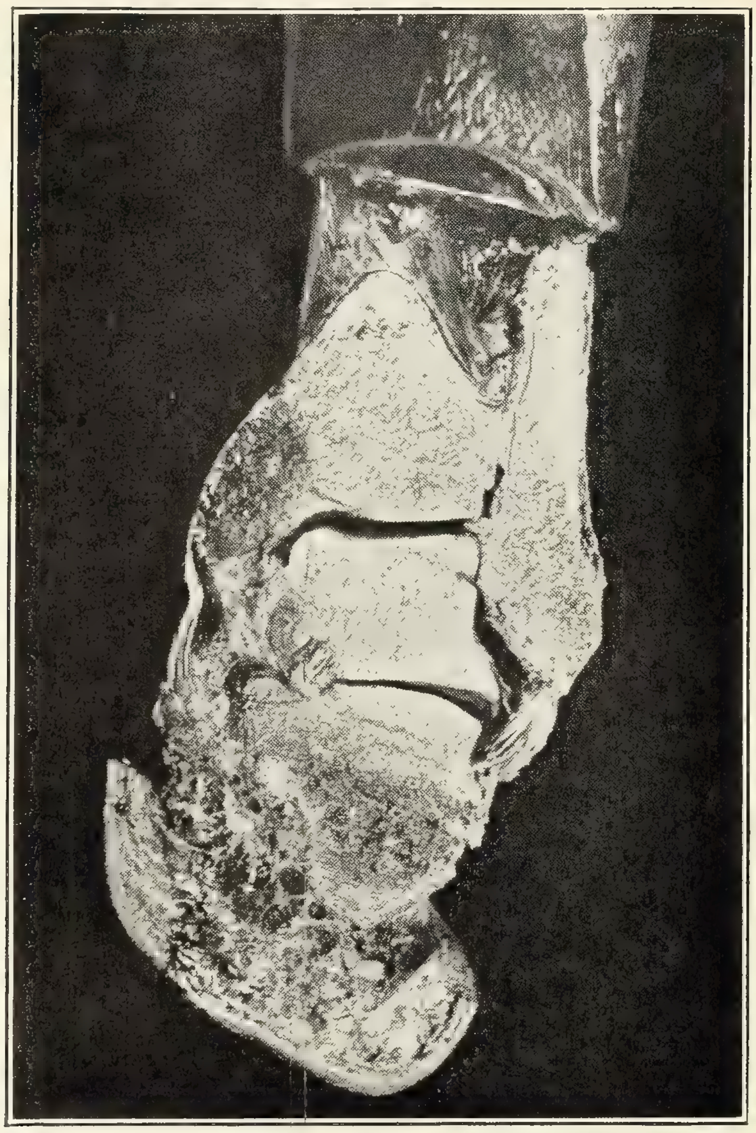

FIG. 367. FRONTAL SECTION OF THE ANKLE-JOINT. Adduction causes tension on external lateral ligament and if forced will tear off the external malleolus.

which, being from 5 to 7 mm. posterior to the median tubercle, is the portion of the astragalus casting the farthest posterior shadow in lateral roentgenograms of the foot. This posterior band of the external lateral ligament is so exceedingly strong that it is very seldom, if ever, ruptured; it holds the astragalus almost indissolubly attached to the external malleolus (Chaput says they are like Siamese Twins); and in injuries to the ankle it is easier for either one of the two bones to which the ligament is attached to be broken than for the ligament to be ruptured. It is usually the fibula that gives way when the strain comes.

The normal movements of the ankle-joint are those of flexion and extension—20 degrees of dorsiflexion and 60 degrees of extension or plantar flexion. This motion occurs around an axis which makes an angle of about 30° with the bimalleolar axis. If movements were possible in the ankle joint around an antero-posterior axis, they should be named adduction (tibial flexion) and abduction (fibular flexion), or movements in the frontal plane toward and away from the median line.

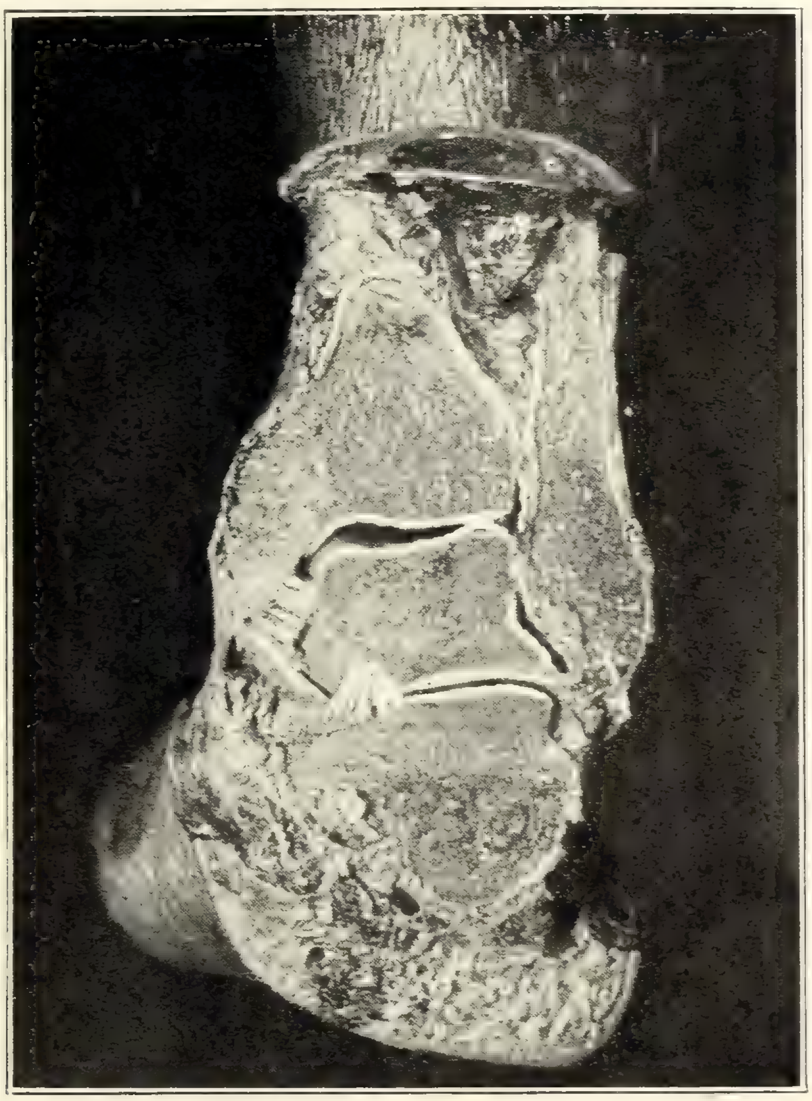

Fig. 368. Frontal Section of the Ankle-Joint. Abduction causes tension on internal lateral ligament and will rupture this or fracture the internal malleolus before outward pressure on the external malleolus will fracture the latter or cause diastasis between tibia and fibula. (Figures 367 and 368 are from a preparation in the laboratory of operative surgery, University of Pennsylvania.)

These movements are quickly resisted by the tension on the lateral ligaments (Figs. 367 and 368), and if forced the malleolus *away from which motion occurs* is torn off by its ligament, or the ligament itself ruptures. Motions of adduction and abduction in the foot normally occur in the subastragalar joint and permit the calcaneum without difficulty to accommodate itself to slight irregularities of the soil. But the calcaneum is attached to the astragalus by the extremely strong astragalo-calcanean interosseous ligament; and when such movements are too extensive, they are transmitted directly to the astragalus and the tibiofibular mortise, and fracture of one or the other malleolus is the usual consequence. Not until that malleolus on which the pull comes has given way, or the corresponding ligament has ruptured, is the astragalus able to act on the other malleolus by a push which will produce a compression fracture.

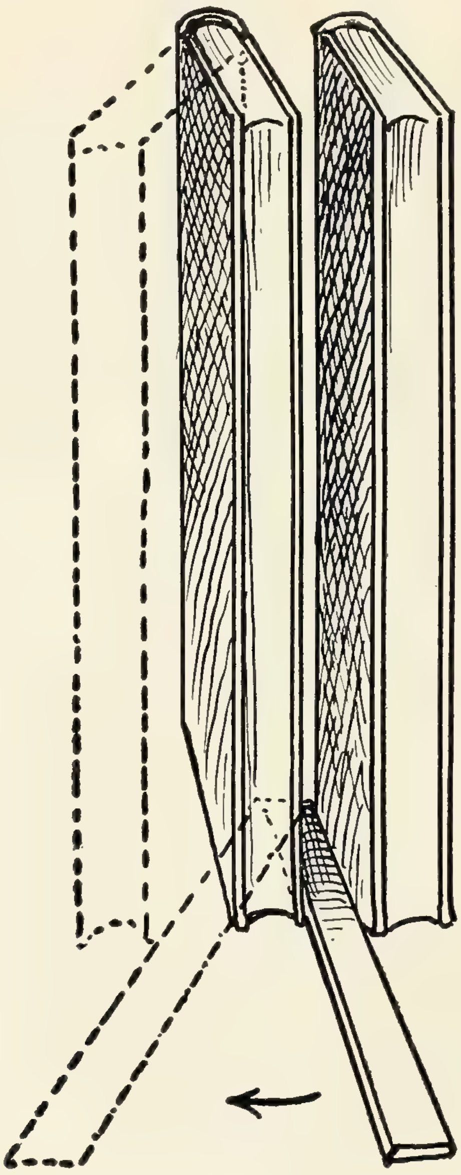

Fig. 369. An Illustration of Maisonneuve's Explanation of Fracture of the Lower End of the Fibula by Outward Rotation of the Foot Around the Axis of the Leg. The books represent the malleoli, and the ruler represents the foot: the volume which is moved is always that toward which the long end of the ruler moves, even if this book is much heavier than the other.

Movements of rotation around the long axis of the leg may be attempted in the ankle-joint by twisting the point of the foot toward or away from the median line. As pointed out by Maisonneuve (1840), movements of inward rotation are almost inseparable from a movement of adduction, as the numerous joints in the anterior tarsus render the foot very mobile in this direction. Any movement toward outward rotation, however, converts the foot into a rigid lever, and motion is readily and with much force transmitted to the ankle-joint, the astragalus attempting to turn so as to bring its long axis crosswise between the malleoli. Owing to physical laws, it is on the external malleolus that the greatest strain occurs (Fig. 369).

Mechanism. Most fractures of the tibia or fibula involving the ankle-joint are due to forced movements in one of three directions:

(A) *Fractures by External Rotation.* In 61 per cent of the cases the fracture is due to rotation of the foot outward around the long axis of the leg, producing *first* an oblique or spiral fracture of the lower end of the fibula (Fig. 370, A1); *second,* if the force continues to act, a fracture of the internal malleolus or a rupture of the internal lateral ligament (Fig. 371, A2). Sometimes, instead of the internal malleolus alone, the whole lower end of the tibia is torn off by a spiral fracture (A3).

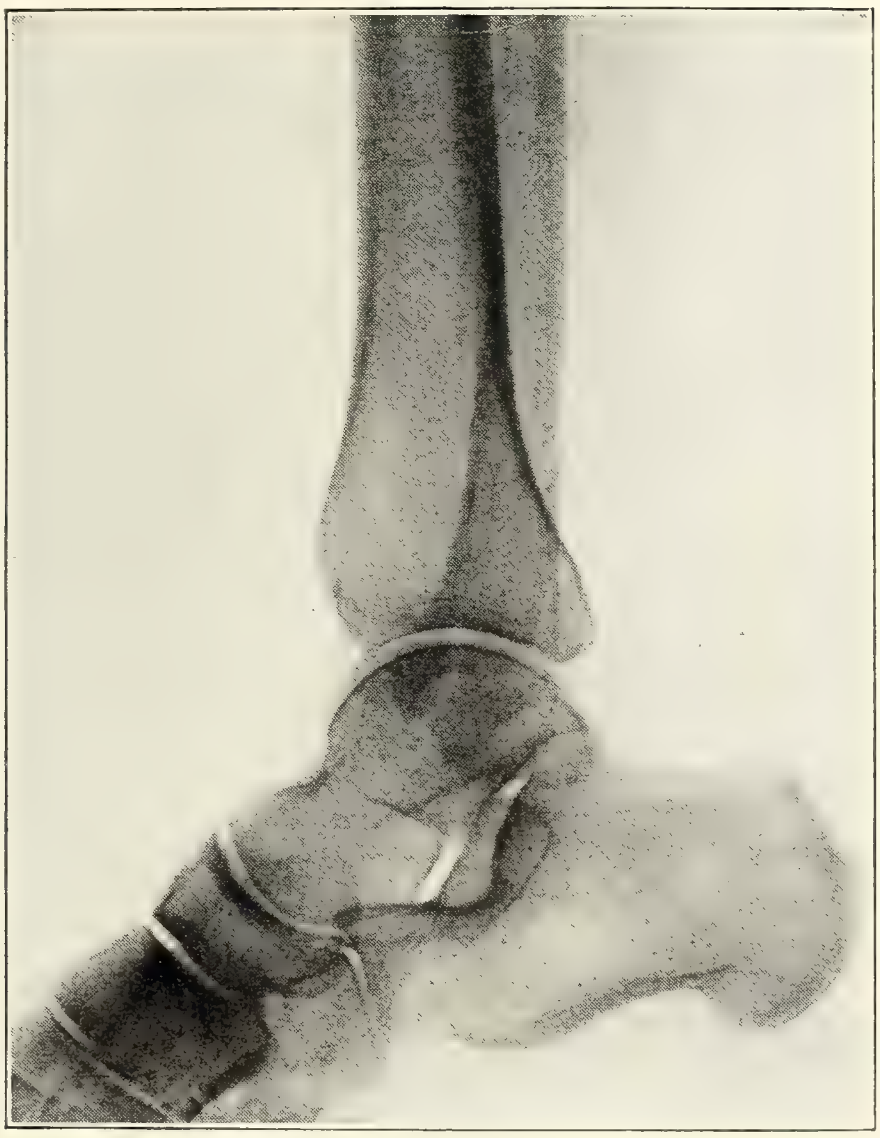

FIG. 370. MIXED OBLIQUE FRACTURE OF THE LOWER END OF THE FIBULA: the first stage of the lesion resulting from external rotation (A, 1). This occurs as isolated lesion in 25 per cent of all cases of fracture of the ankle; as combined lesion, in 61 per cent. Usually invisible in anteroposterior views.

(B) *Fractures by Abduction,* or fibular flexion of the foot, are second in frequency to those just mentioned, constituting 21 per cent of the cases. There occurs *first* a fracture of the internal malleolus (Fig. 373, B1) or rupture of the internal lateral ligament; *second,* if the force continues to act, a fracture of the fibula (external malleolus below the inferior tibiofibular joint (Fig. 374, B2a), or, if these ligaments rupture,

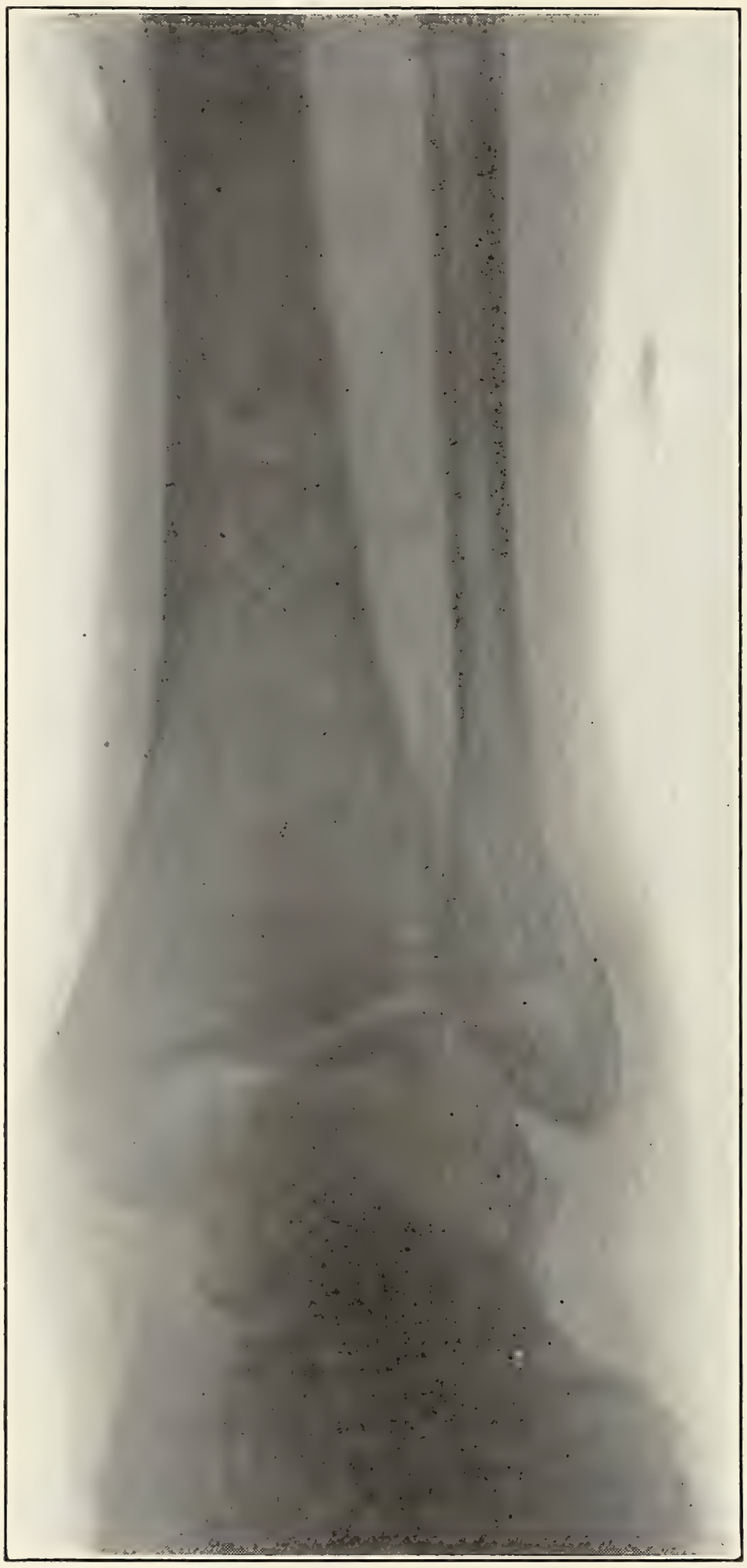

Fig. 371. Mixed Oblique Fracture of Fibula, with fracture of internal malleolus (or rupture of internal lateral ligament); complicated by a posterior marginal fracture of the tibia, with posterior displacement of the foot. This fracture may be designated A2x, where A stands for the *mechanism* (external rotation) 2 for the *stage,* and x signifies the most frequent complication. Antero-posterior view before reduction. For lateral view see Fig. 371b. Male, age 54 yrs.

as is usually the case, a fracture of the fibula above the ligaments—the fracture (Fig. 375, B2b) usually known by the name of Pott (1769) or of Dupuytren (1819). Occasionally the whole lower end of the tibia, instead of the internal malleolus alone, is fractured.

(C) *Fractures by Adduction,* or *tibial flexion of the foot,* are comparatively rare (13 per cent of the cases). The *first* lesion is a transverse fracture of the external malleolus (i. e., below the inferior tibio-fibular ligament) (Fig. 376, C1); the *second,* if the force continues, is fracture of the internal malleolus by compression (C2a) or the splitting off of the median border of the tibia (Fig. 377, C2b).

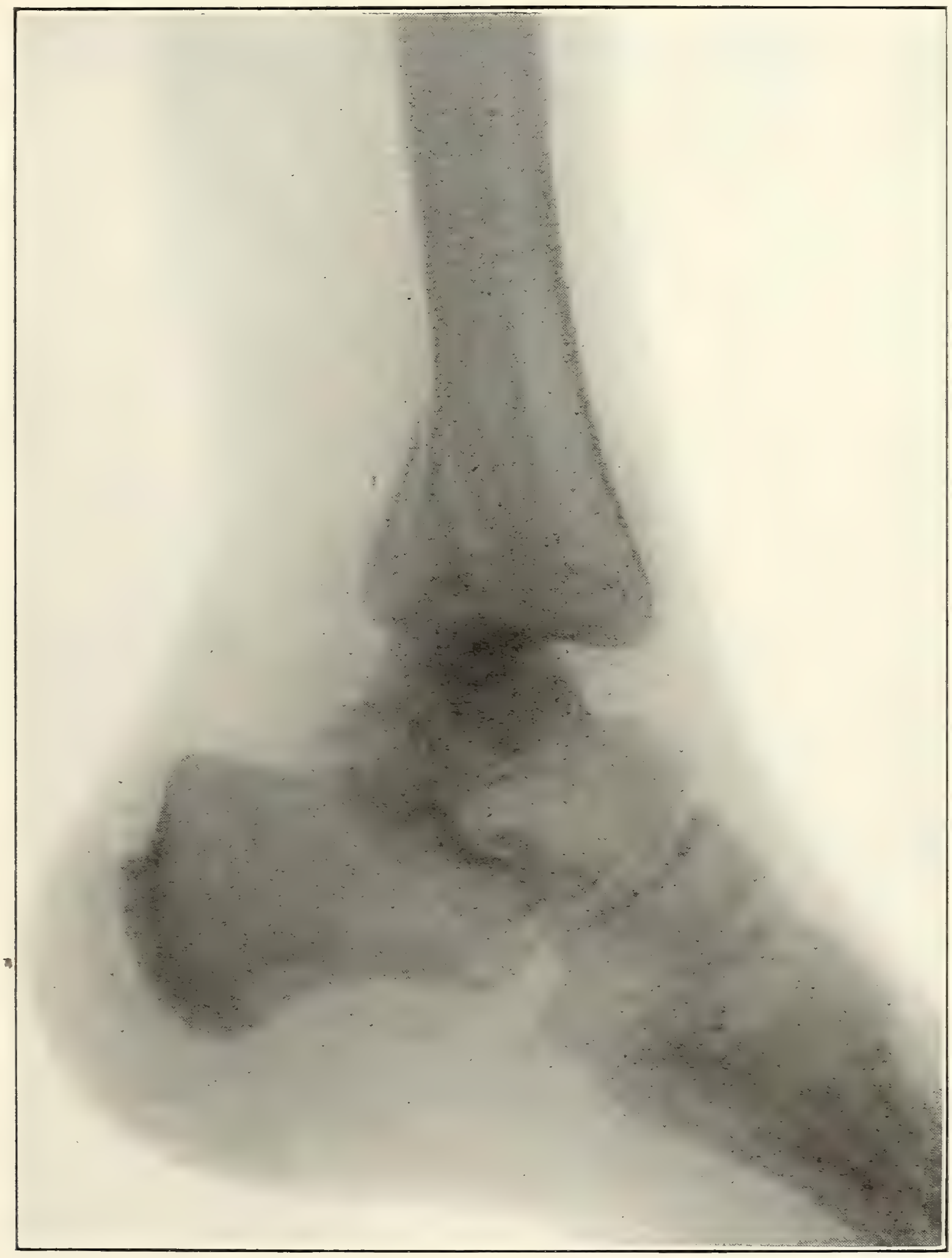

FIG. 371b. See Fig. 8b for position after reduction.

(D) *Splitting Fractures* (T or Y fractures) of the articular surface of the tibia are sometimes seen, caused by violence transmitted upward from falls on the foot (Fig. 378).

(E) *Fractures by Direct Violence* (crushes) usually are comminuted and occur just above the ankle-joint. Often they are compound.

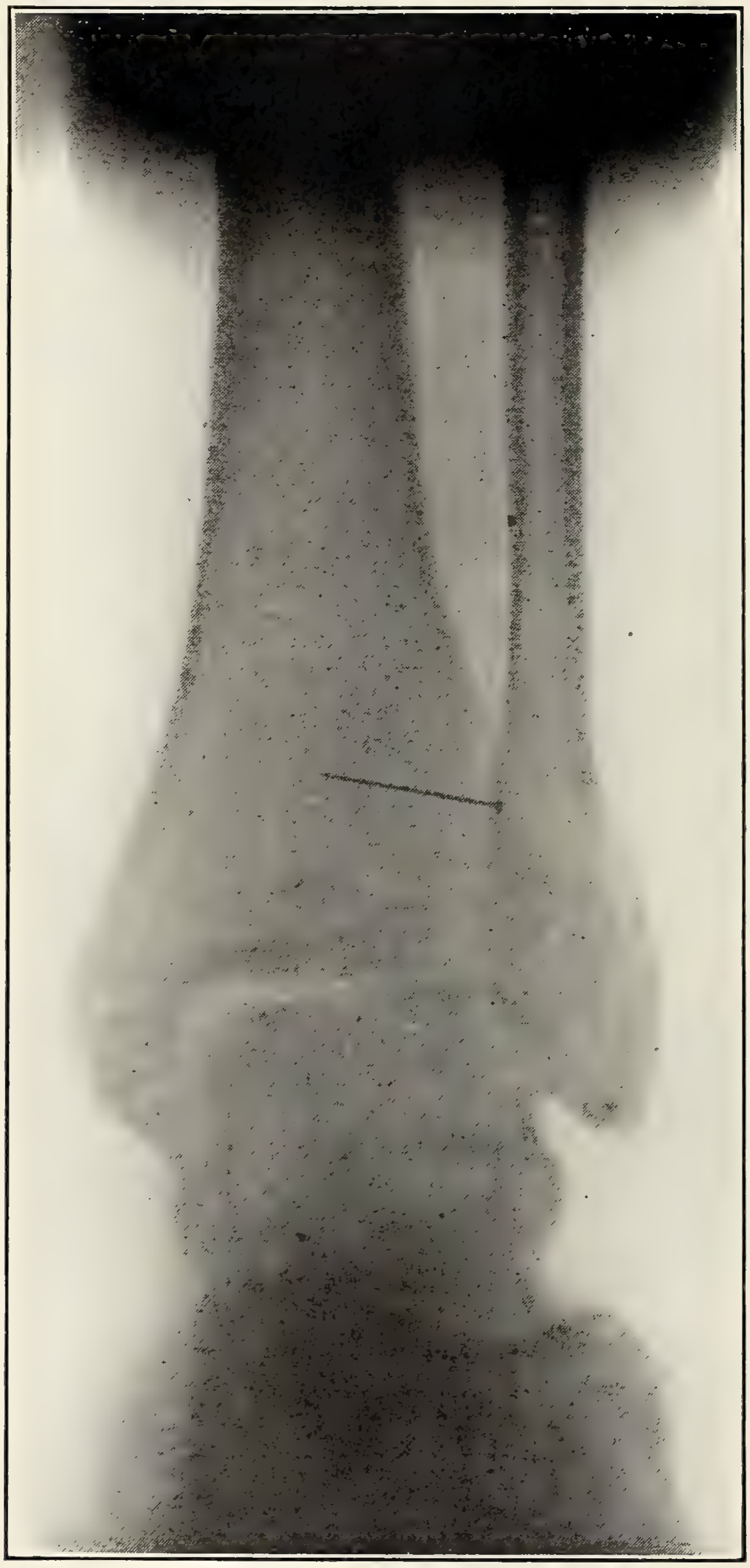

Fig. 372. Fracture Shown in Fig. 371 (A2x) After Reduction. Patient seen first 3 weeks after injury, and reduction was not quite complete, even after tenotomy of the tendon of Achilles. For lateral view, after reduction, see Fig. 372b. Useful leg, but not perfect function.

Classification According to Mechanism	Per Cent
A. Fractures by External Rotation	
1. First Degree: Lower end of fibula only ("mixed oblique")	26.
2. Second Degree: Same, *plus* rupture of internal lateral ligament or fracture of internal malleolus ("low Dupuytren")	33.
(a) Internal lateral ligament	
(b) Internal malleolus	
3. Third Degree: Same, *plus* fracture of the whole lower end of tibia, representing the internal malleolus	1.7
Total Fractures by External Rotation	61.
B. Fractures by Abduction (Fibular Flexion)	
1. First Degree: Internal malleolus only	6.6
2. Second Degree: Same *plus* fracture of fibula (transverse, above or below tibiofibular joint)	13.7
(a) Below inferior tibiofibular joint (no diastasis) ("bimalleolar fracture")	
(b) Above inferior tibiofibular joint (with diastasis) ("Pott's fracture," "Dupuytren type")	
3. Third Degree: Internal malleolus represented by whole lower end of tibia	0.66
Total Fractures by Abduction	21.
C. Fractures by Adduction (Tibial Flexion)	
1. First Degree: External malleolus only, transverse, at or below level of tibial plafond	9.
2. Second Degree: Same, *plus*	3.6
(a) Internal malleolus below level of tibial plafond ("bimalleolar fracture")	
(b) Median surface of tibia up and in from joint surface	
3. Third Degree: Same, *plus* whole lower end of tibia ("supramalleolar fracture by adduction")	0.66
Total Fractures by Adduction	13.3
D. Fractures by Compression in Long Axis of Leg	2.7
E. Fractures by Direct Violence (Supramalleolar types)	1.7

Causes. Most fractures of the ankle occur as the patient is walking. The foot catches in a rut while the body continues to move, or it suddenly slips from under the patient and he falls on it, breaking the ankle by the weight of his body. Jumps and falls from a height may produce compound fractures by protrusion of the bones.

Complications. One of the most frequent complications is a *fracture of the posterior articular margin of the tibia,* caused by a direct upward and backward thrust by the astragalus, sometimes aided by an avulsing force through the posterior band of the inferior tibiofibular ligament. This complicating fracture, which occurs most frequently with fractures by external rotation of the foot (Fig. 371b) often is responsible for a *posterior dislocation of the foot.* The latter is very rare without a posterior marginal fracture.

Emergency Treatment. If there is great deformity, any bystander will be anxious to pull the foot as nearly straight as possible; and provided this is done with a certain intelligence and not too violently, it is a good thing; since if the fracture is left fully unreduced for any considerable time there is danger that the bones (especially the tibia above the fractured internal malleolus) may rupture the skin and produce a compound fracture. If a wound of the skin already exists, it should be protected by a sterile compress; or, if no sterile dressing is

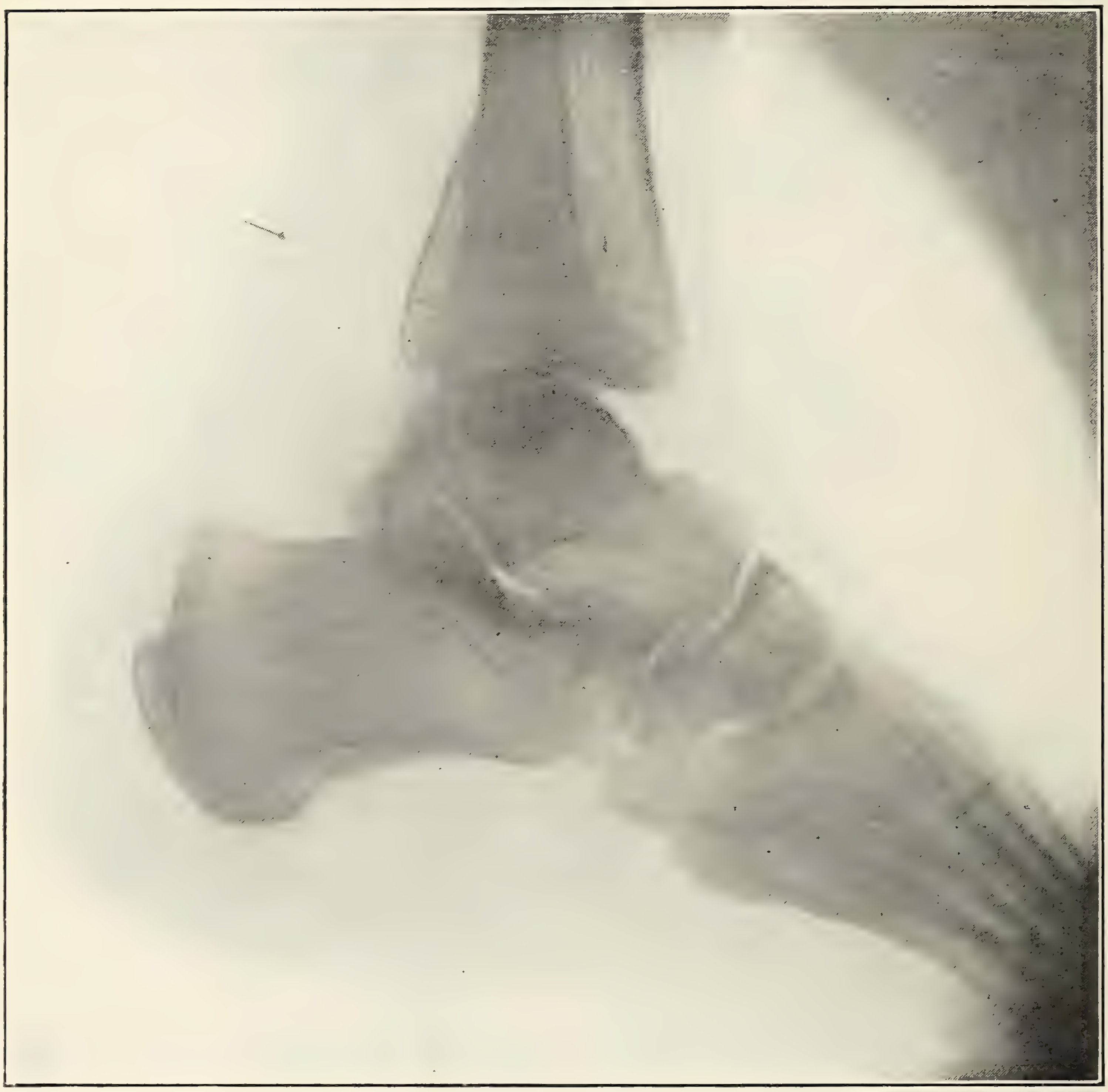

Fig. 372b. Fracture Shown in Fig. 371b After Reduction

available, with a compress soaked in alcohol. If iodin is used it should be allowed to dry on the wound before the latter is covered up. Transportation is best endured after tying the foot and leg snugly in a pillow, which may be reinforced on its outer surfaces by strips of board or by twigs. As soon as skilled help is available the shoe should be removed (cut off if necessary), the foot washed and shaved, and preparations made for reduction of the fracture and its permanent fixation.

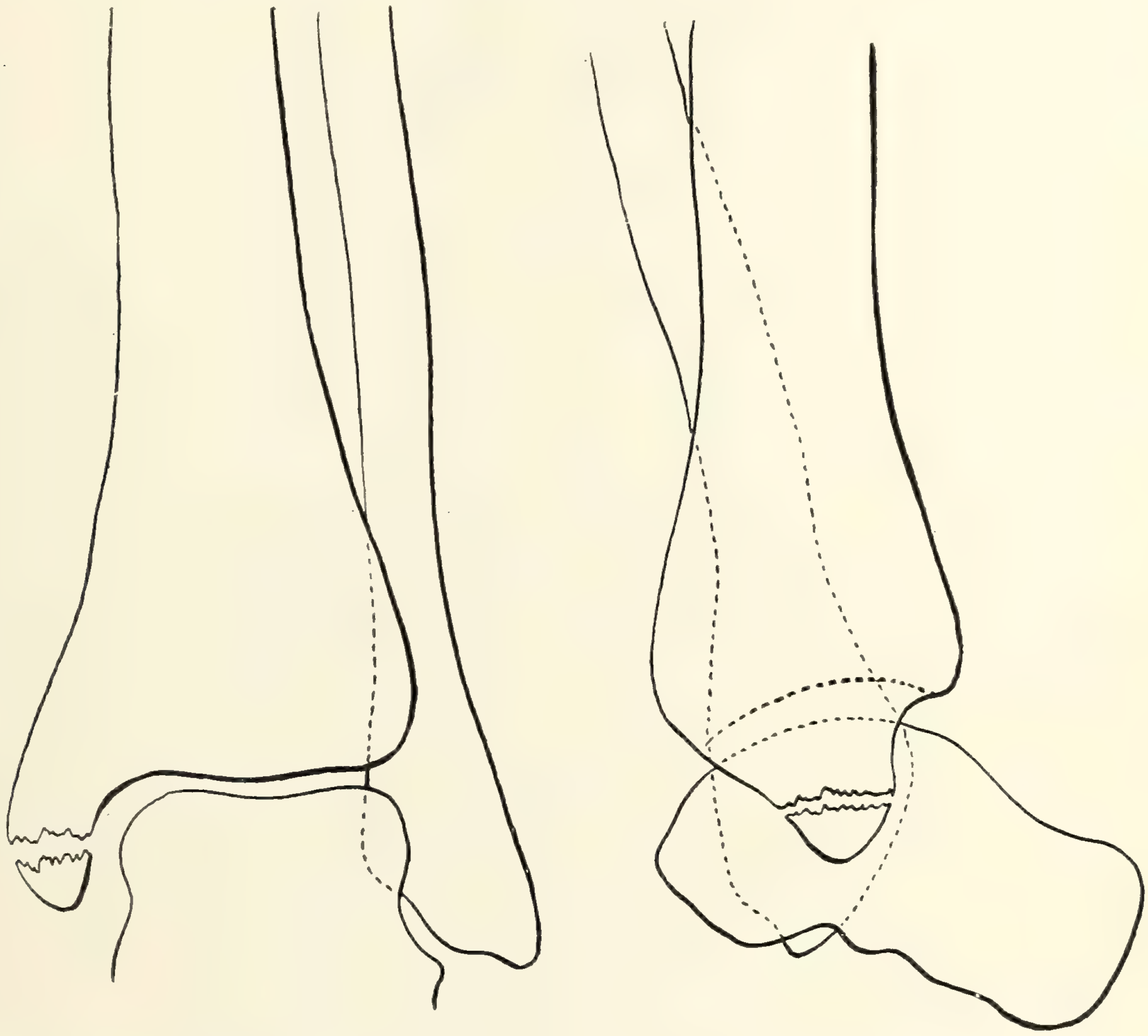

FIG. 373. ABDUCTION FRACTURE, FIRST DEGREE (B, 1): avulsion of internal malleolus. This fracture occurs in 6.6 per cent of all fractures at the ankle. All forms of the abduction type together comprise about 21 per cent of the cases.

Symptoms and Diagnosis. Before marked swelling occurs, the diagnosis of the lesions present usually can be made by intelligent digital examination, and the X-Ray is needed merely for confirmation of the diagnosis. After swelling has developed, clinical examination without the X-Ray is not very reliable. Skiagrams in at least two planes (antero-posterior and lateral) are indicated in all cases, not only before reduction is attempted, but also afterwards, to determine the position of the fragments.

The *sites of greatest importance* in searching for tenderness in a fracture of the ankle are: (a) the fibula, both above and below the

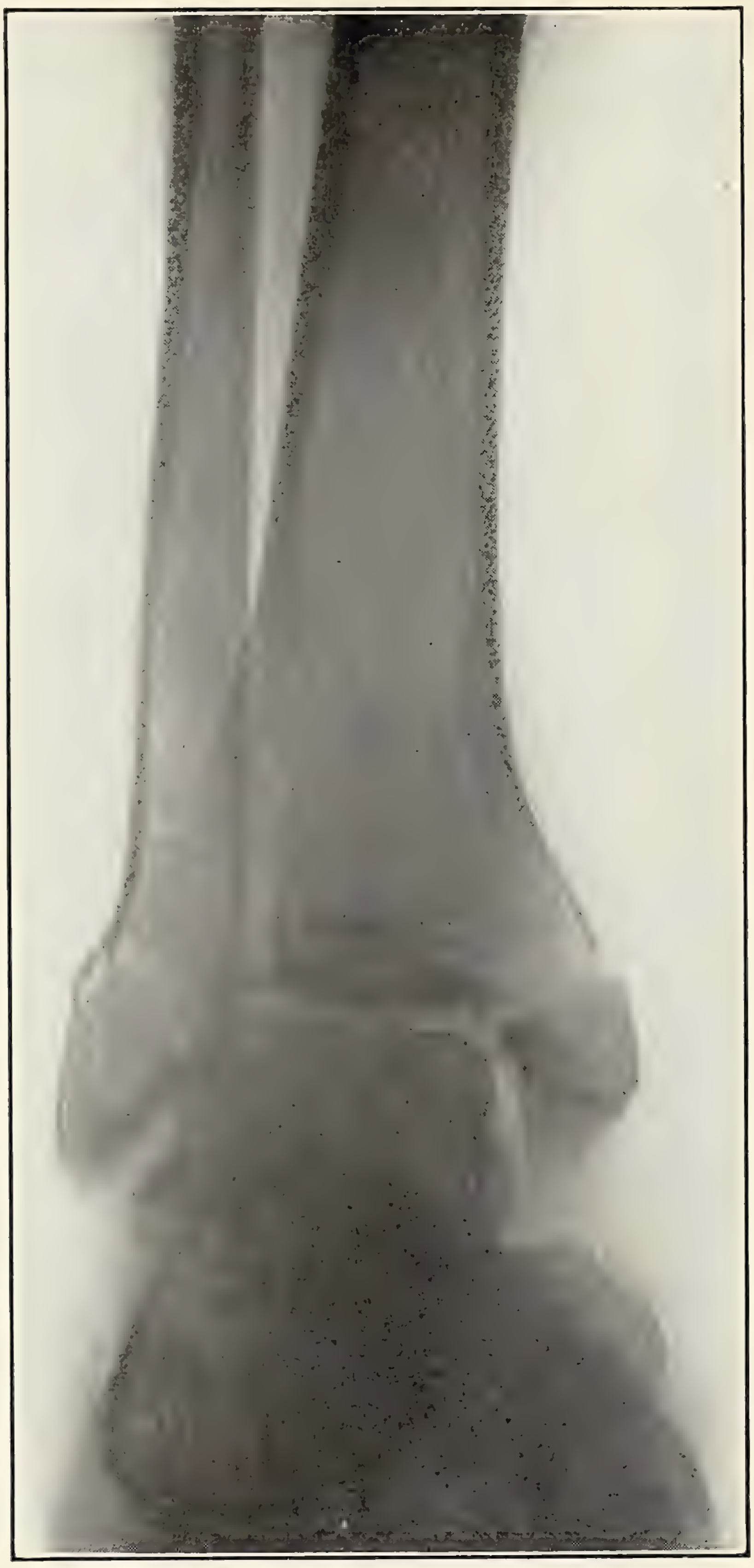

FIG. 374. BIMALLEOLAR FRACTURE BY ABDUCTION (B2a): B represents the mechanism, 2 the stage (both bones involved), and a indicates that the fibula (the second bone to break) is fractured *below* the inferior tibiofibular ligaments. This is a rare fracture. Fractures of the B type above these ligaments, which are more frequent, are shown in Fig. 375 and are indicated by the notation B2b. Male, 42 yrs.; while standing at work, an iron I-beam lying on the ground beside him was tipped over, striking lateral surface of leg and forcing foot into fibular flexion. Did not lose his footing and was able to walk a little.

inferior tibiofibular ligaments; (b) the internal malleolus; and (c) the inferior tibiofibular joint.

1. If there is pain and tenderness to palpation over the *fibula alone,* the lesion is the first stage either of the fracture by external rotation or of that by adduction. If the tenderness is confined to the tip of the fibula, not extending above the inferior tibiofibular joint, the lesion is due to adduction (Fig. 376); if the tenderness extends to the lower fifth of the fibula, distinctly above the inferior tibiofibular ligaments, it is a fracture by external rotation (Fig. 370). In neither case is there displacement of the fragments, since to permit this the tibia also must be fractured, or the internal lateral ligament ruptured.

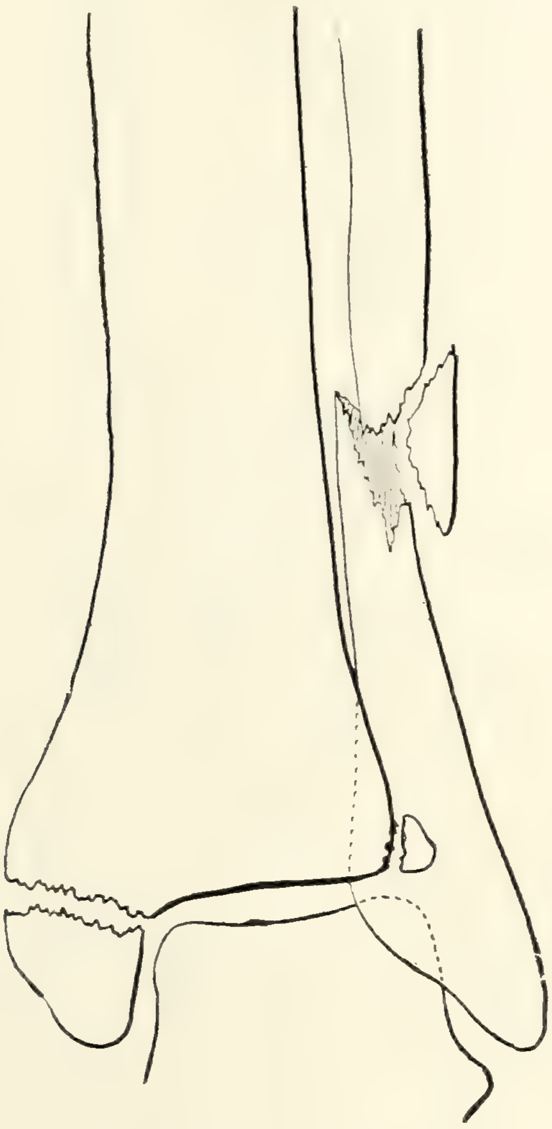

FIG. 375. FRACTURE BY ABDUCTION, second degree (B2b) (Pott's fracture, Dupuytren type): diastasis evidenced by detachment of fragment from anterior tubercle of tibia (intermediate fragment); fracture by bending clearly shown by detachment of wedge from concave side of fibula.

2. If there is pain and tenderness to palpation over the *internal malleolus alone,* the lesion is the first stage of a fracture by abduction or fibular flexion (Fig. 373); and there will be little or no displacement.

3. If there is pain and tenderness over *both malleoli,* but not over the inferior tibiofibular joint, it is a "bimalleolar" fracture (Fig. 374), sometimes due to abduction (fibular flexion), but usually due to adduction (tibial flexion) and forming the second stage of the fracture indicated in Fig. 376. The foot may be displaced laterally either inward or outward, but as a rule it is not rotated much on its long axis or on that of the leg.

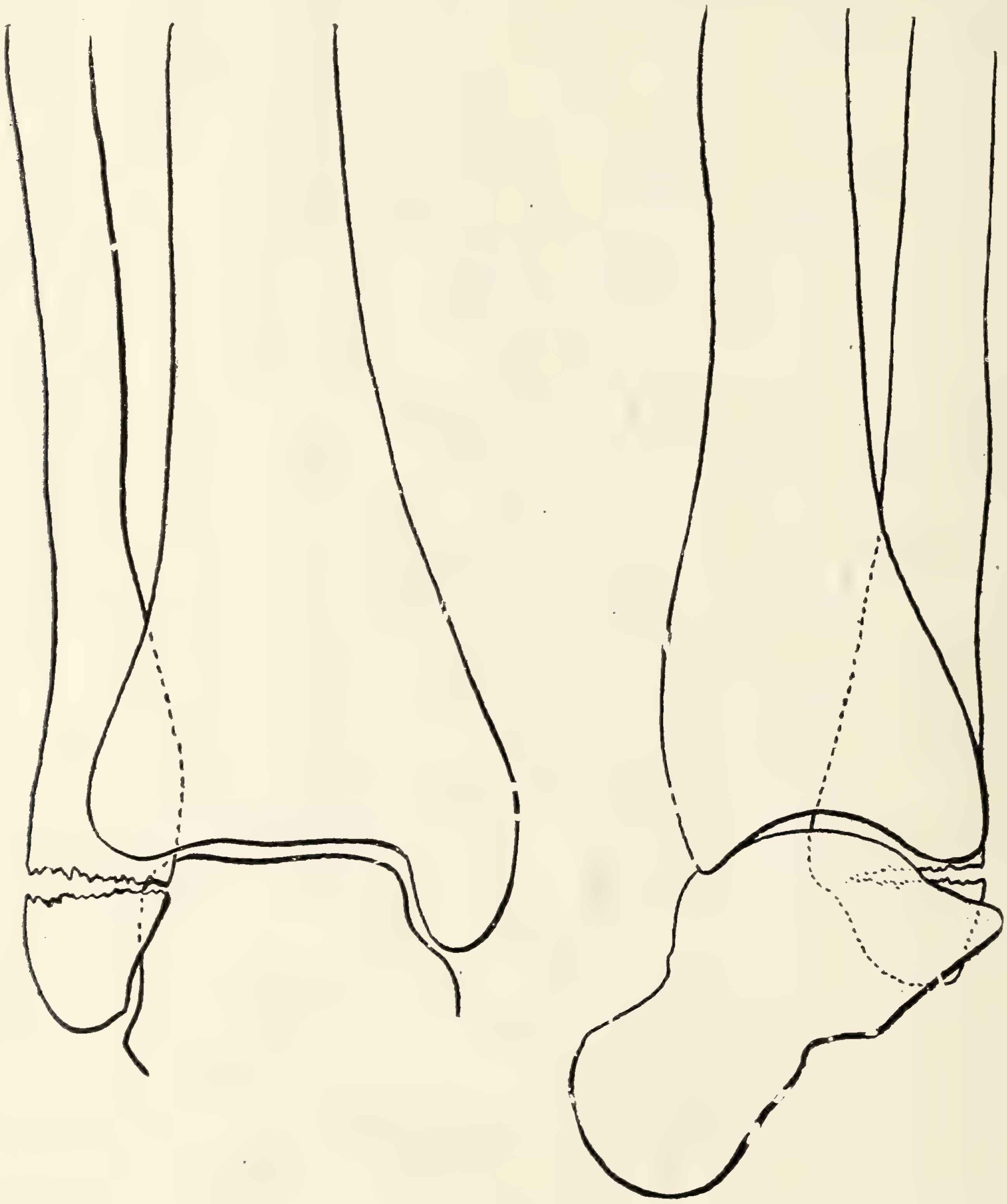

Fig. 376. Fracture by Adduction, first degree (C, 1); avulsion of external malleolus.

4. If there is pain and tenderness over the *internal malleolus and over the inferior tibiofibular joint,* the fracture is one by abduction (fibular flexion). This combination is rare unless there is also a *fracture*

of the fibula above the inferior tibiofibular joint, characterized by persistent tenderness and often by crepitus and abnormal mobility of the fibula at this point (Fig. 375). In these cases there may be marked lateral displacement of the foot outward on the leg bones, and also outward rotation of the foot on its long axis, so that the median border

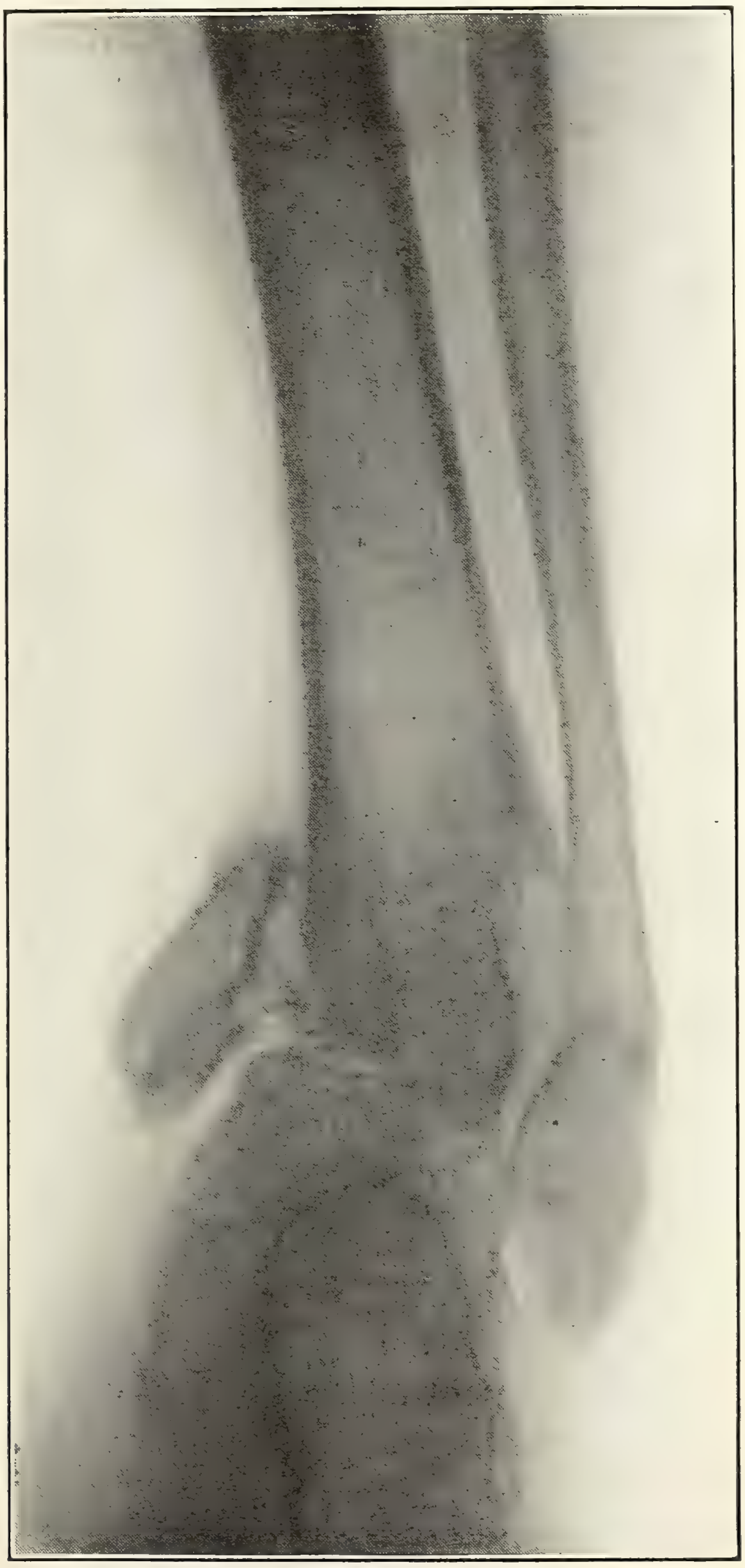

Fig. 377. Bimalleolar Fracture by Adduction (C2b): C represents the mechanism, 2 the stage (both bones involved), and b means that not only is the internal malleolus fractured, but that a splitting fracture has taken place up the median border of the tibia.

of the foot is turned downward and the sole looks outward. There seldom is much if any posterior displacement.

5. If there is pain and tenderness over the lower end of the fibula *above and below* the inferior tibiofibular joint, with the same symptoms over the internal malleolus, the fracture is one by external rotation of the foot around the long axis of the leg (Fig. 371), and there may be great displacement of the foot; its forward extremity may even be

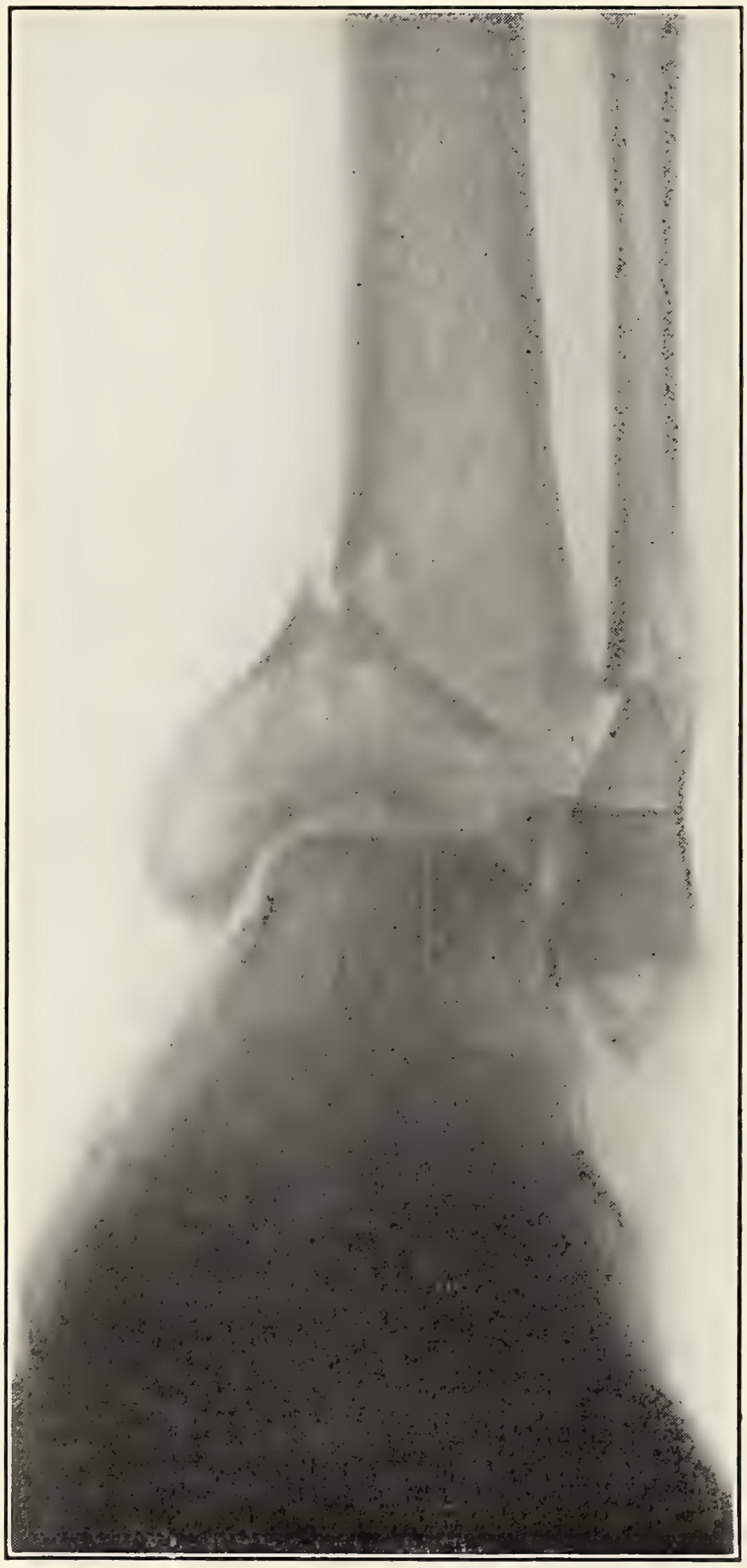

Fig. 378. T or Y Fracture of the Ankle, from compression upward (D).

turned outward until the outer border of the foot lies on the bed even when the leg bones remain in the anatomical position. This fracture is often complicated by a posterior marginal fracture of the tibia, and this should be suspected if there is pain and tenderness and perhaps undue swelling in the hollow between the tibia and the tendon of Achilles, and especially if there is posterior subluxation or dislocation of the foot. In the latter case the lower end of the tibia makes a prominence under the extensor tendons at the front of the ankle-joint, and the foot appears shortened while the heel is lengthened.

Treatment. In all cases of injury about the ankle-joint, X-Ray pictures should be made in at least two planes; and every patient should be treated as if a fracture existed until the contrary can be proved.

1. If the fracture is *subperiosteal* and *there is no displacement,* it is sufficient to apply adhesive strapping as in a case of sprain; but *weight bearing should not be allowed* until the bone has had time to unite. And in all cases (except in fractures by adduction) it is well to have a shoemaker raise the inner borders of the sole and heel of the patient's shoe about 4 or 5 millimetres, so as to overcome the tendency toward development of pronated or flat feet, which are frequent sequels of these injuries. In fractures by adduction, attention to the shoes seldom is necessary; but if the patient during convalescence persistently tends to sprain his ankle in recurring adduction, the outer side of the heel and sole should be raised.

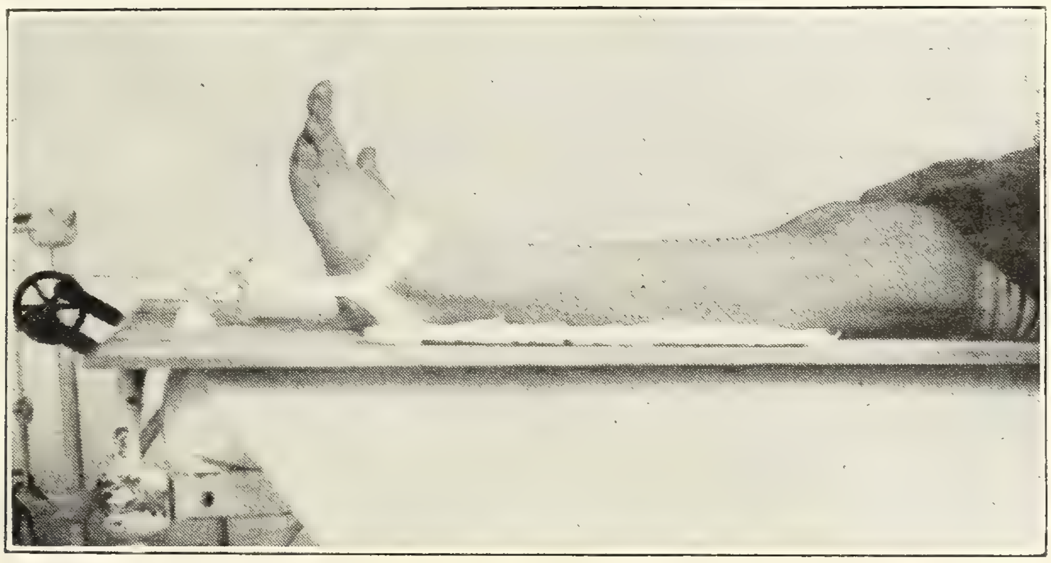

FIG. 379. METHOD OF APPLICATION OF DELBET'S APPARATUS FOR FRACTURES OF THE LEG. Note the board laid on the bed, with pulley for weight extension; the traction loops over instep and heel, and the Scultetus bandage beneath the leg.

2. *Fractures with displacement* must be reduced as soon as possible after the accident. Early reduction is much easier and will frequently prevent the development of injurious swelling.

(1) Reduction may be secured by *Delbet's method of continuous weight extension* by a stirrup applied over the instep and heel. This secures rapid reduction, in the course of ten or fifteen minutes, without the use of a general anæsthetic, and without causing any pain. When reduction is complete, Delbet's apparatus of plaster of Paris is applied, and when this has set, the weights and traction stirrup are removed.*

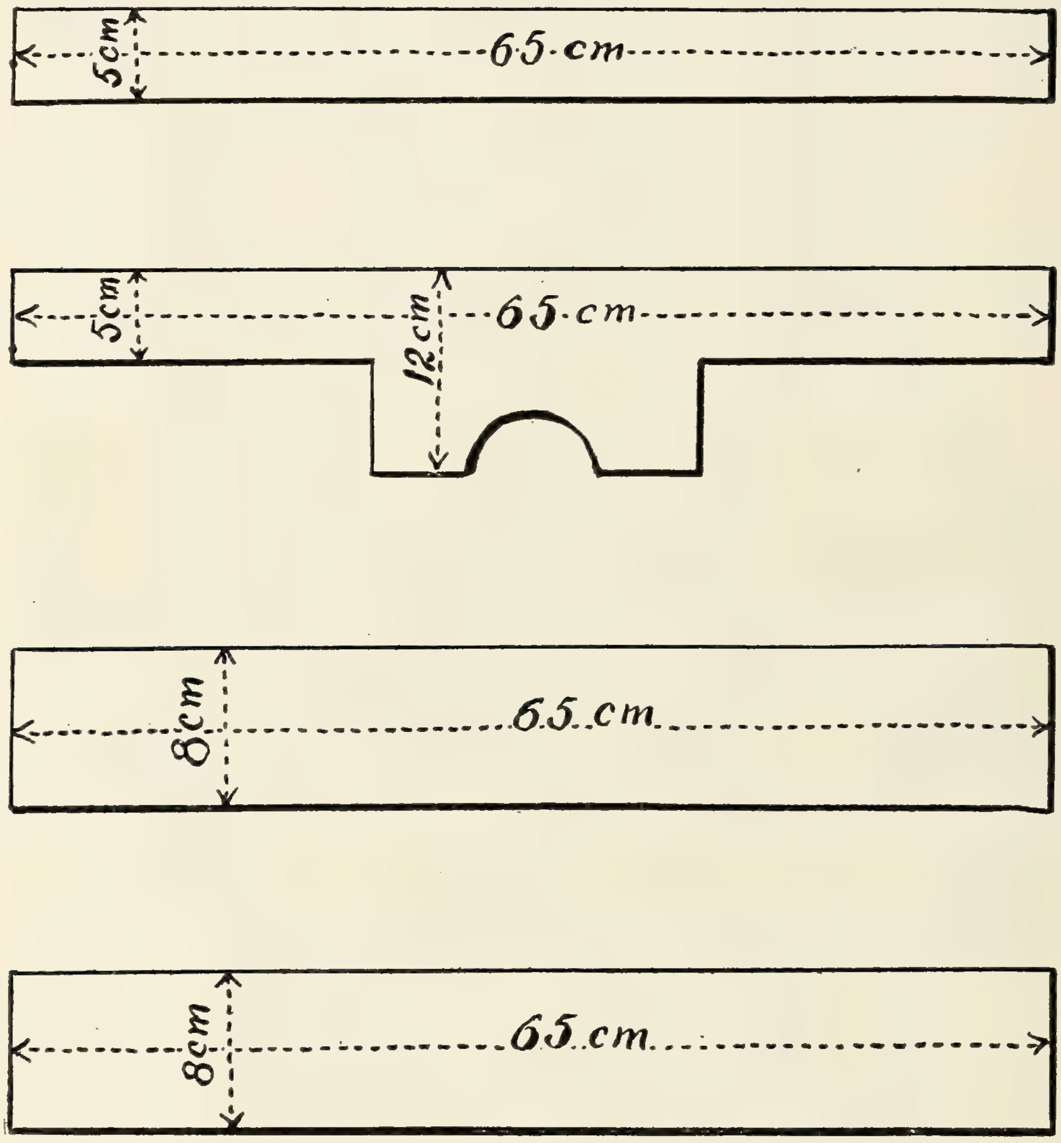

Fig. 380. Diagram Showing the Dimensions of the Crinoline Bands of Which Delbet's Apparatus is Composed. The two lateral bands are made of 24 thicknesses of crinoline, and the circular bands of 16 thicknesses each.

Delbet considers this method especially applicable to fractures of the ankle. He says (1916), quaintly enough, that before he had perfected this method he constantly prayed that if ever he had to experience any fracture in his own person it might not be one of the ankle, since the results of ordinary treatment were so bad; but since adopting the method which is about to be described, he prays that he may suffer an ankle fracture rather than any other, because the treatment and results are so satisfactory.

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* See Ashhurst and Crossan: Prognosis and Treatment of Fractures of the Tibia and Fibula. (Trans. Amer. Surg. Assoc., 1923, xli, 594.)

The Delbet apparatus should be applied as soon after the accident as possible, before swelling develops: prompt reduction of the fracture is the best means to prevent the occurrence of injurious swelling. The chief advantages of the apparatus are: (1) It is applied during continuous traction on the foot by weight and pulley, this traction serving to secure accurate reduction of the fracture without any anæsthetic; (2) as soon as the plaster of Paris has set, the weight extension may be removed, since the apparatus fits snugly to the condyles of the tibia above and to the malleoli below, preventing any subsequent displacement; (3) it leaves both the knee and ankle-joints free, so that the patient can move them from the start, and thus by constant use of his leg muscles can materially shorten the period required for consolidation of the bones, and prevent occurrence of the atrophy of disuse; (4) the patient can leave his bed and begin to walk with crutches during the first week or ten days; (5) the *average* time the splint was worn in Delbet's own cases, was 35 days, the fragments being then firmly united and all external support discontinued.

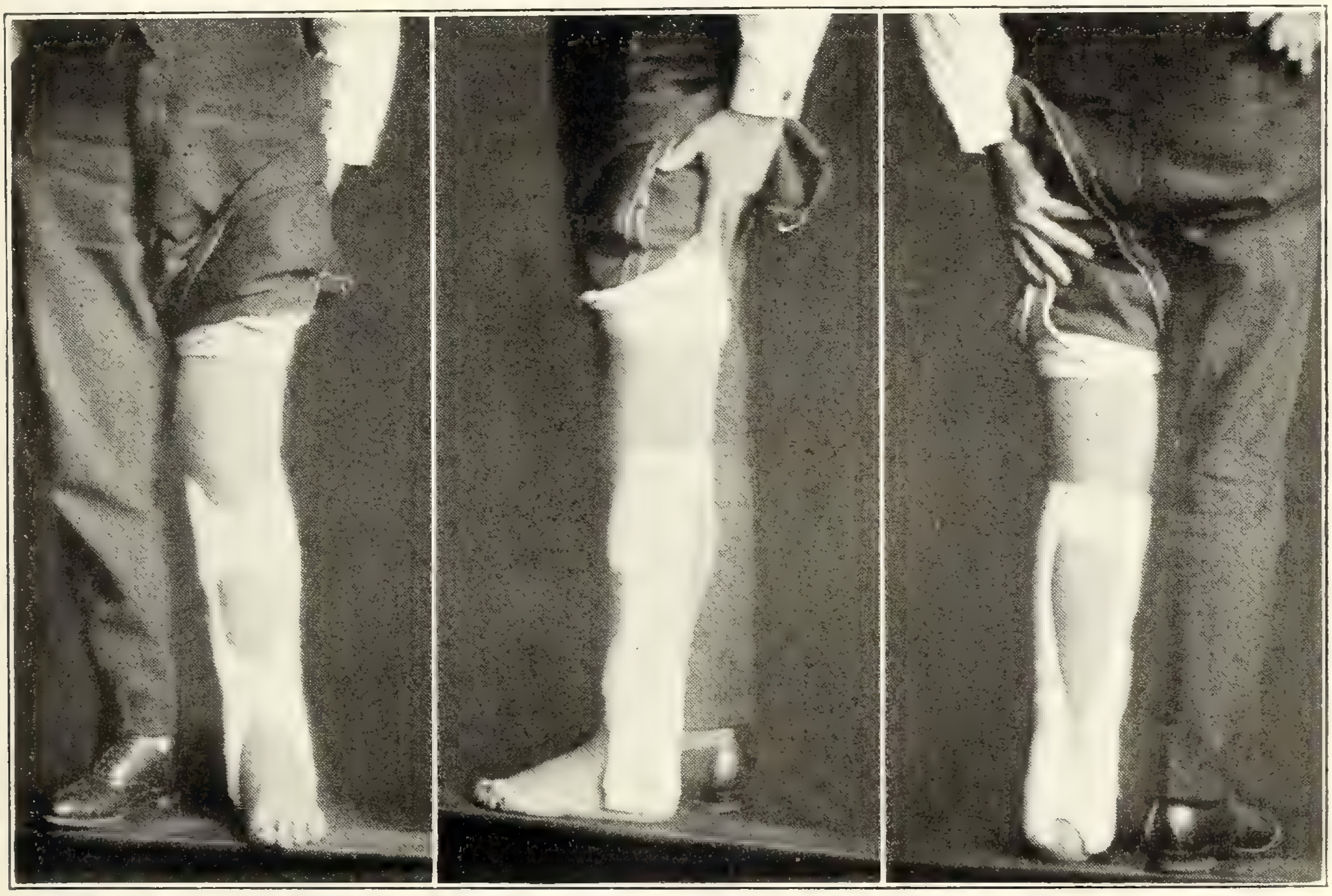

FIG. 381. DELBET'S APPARATUS FOR FRACTURE OF THE LEG. Note that the weight is borne on foot itself, not on ends of the splint. The *lower* band crosses above the prominence made by contraction of the tendon of the tibialis anticus; the *upper* band should not come so far below the tubercle of the tibia as to press on the crest of the tibia. Note also the space for projection of heel.

The materials required for the application of the apparatus are:

1. A hard flat table with no padding, to support the fractured leg. Such support prevents the posterior sagging always seen when the limb is placed on an upholstered surface, such as even the firmest mattress. It has proved convenient to use a thin board which is laid on top of the mattress (Fig. 379). A pulley is attached to the board at such a height that traction over it will be directly in the axis of the leg bones; and the pulley being movable laterally on its axis, any lateral deformity at the site of the fracture can be corrected by shifting the pulley to right or left without in any way disturbing the limb.

2. A Scultetus (many-tailed) bandage, made by stitching together at their centers enough rather narrow strips of bandage (each about 50 cm. long) to extend from the heel to the knee. The ends of this bandage may be wrapped around cardboard strips for convenience in handling.

3. Weights for traction. From 7 to 10 Kg. (16 to 22 lbs.) are required.

4. Material such as tarlatan or crinoline for making the apparatus. This should be cut into pieces of the following dimensions (Fig. 380): the *two* side splints are each of 24 thicknesses, and 65 cm. long by 8 cm. wide; the band which encircles the leg below the knee is of 16 thicknesses, and 65 cm. long by 5 cm. wide; the band which encircles the malleoli and heel is also of 16 thicknesses, 65 cm. long, and cut so that its middle portion is 12 cm. wide by 19 cm. long, while its right and left thirds are only 5 cm. wide and each 23 cm. long: in the middle third a semicircular notch is cut in the projecting portion to receive the point of the heel. Each of these four splints should be basted down its middle from end to end, for convenience in handling.

Application of the Delbet Apparatus. The board with pulley attached is placed under the fractured leg with as little disturbance as possible, and an assistant holds the patient's toes to prevent rotation of the foot on the leg. The leg is cleansed and if necessary shaved. It should always be very well powdered (talc powder is excellent). As the plaster of Paris splints are to be applied directly to the bare skin, discomfort may arise from the hairs sticking to the plaster while moist. Shaving will prevent this, but generous powdering is sufficient, and is more satisfactory than greasing, which tends to prevent the plaster from setting. Next, the Scultetus bandage is carefully drawn under the leg, without disturbing the latter more than is absolutely necessary. A stirrup for traction is then made by passing one strip of flannel bandage (about 3 cm. wide by 45 cm. long) beneath the tendon of Achilles, and another of the same dimensions across the dorsum of the foot just below the ankle-joint. These strips are arranged so that their centers lie in the midline of the heel and ankle, and they are overlapped just *below* and *posterior* to the malleoli. While the surgeon holds the ends properly overlapped, the nurse sews them together; this may be facilitated by turning the overlapped ends temporarily upward above the malleoli. It is important to have the stirrup fit the ankle snugly, and to overlap the strips far enough posterior to the malleoli to prevent the line of pull from tending to force the foot into the equinus position. Finally, the free ends of these traction slips are sewed or tied to each other at a convenient distance below the sole of the foot; and to the loop thus formed is fastened the cord passing over the pulley and supporting the weights. The weights should be added gradually up to a maximum of 10 Kg. Frequently less weight is enough. As soon as the weights begin to act, the patient's pain ceases. No effort should be made to push or mould the bones into position. Any such attempt will produce pain and muscular spasm, and will totally defeat the object gained, which is the gradual reduction of the deformity. The line of pull may be altered readily by shifting the pulley to one side or the other, without causing the patient any discomfort. As soon as reduction has been secured, as ascertained by measurement and the restoration of the normal contour of the ankle, a plaster cream should be made. About six cupfuls of cold water are placed in a rather shallow but large basin, and plaster of Paris is slowly sifted into the water until the powder no longer sinks rapidly. By this time a little plaster will have collected on the bottom of the basin; and then, but not until then, should the hand be put into the cream for stirring it. This stirring should be done slowly, regularly, and uniformly; no churning is permissible. Delbet says it is better to have a cream too thin than too thick. The plaster should be of the best quality, quick setting, and fresh. When the mixture is of the consistence of very thin cream, all four of the crinoline splints should be immersed at the same time, to prevent unequal distribution among them of the plaster of Paris. Sufficient time should be allowed for them to become well impregnated; they are then removed from the cream and spread out flat and in order, and their surfaces sprinkled with dry plaster of Paris. The band which goes around the malleoli is drawn under the bridge formed by the tendon of Achilles, *without moving the leg,* and is pulled down by see-saw motions until arrested by the heel; for the time being its ends are spread out flat on the fracture board. The band which goes below the knee is next pulled beneath the popliteal space, and is drawn downwards by see-saw motions until arrested by the calf; and its ends are spread out flat on the fracture board. The two lateral bands next are applied, beginning just below the level of the knee joint (this is at the lower border of the patella), and extending to within a centimetre of the sole of the foot at the heel; the bands are then doubled back on themselves, so that the lower third of the leg is supported by a double thickness. When these lateral bands have been gently moulded to the sides of the leg and the malleoli, the circular band already in place beneath the ankle is drawn snugly around the malleolar region on top of the two lateral bands but *without any constriction.* The long ends of this circular malleolar band are to be crossed on themselves over the front of the leg at a point *above* that at which the tendon of the tibialis anticus becomes subcutaneous. This point may be observed on the normal leg, and the splint arranged to correspond. Neglect of this will lead to the development of a pressure sore at this point. Finally the upper circular band, surrounding the condyles of the tibia, is drawn snugly *but without constriction* around the leg below the knee, and its ends are crossed in front at a point above the crest of the tibia, which is also liable to pressure sores. A common mistake is to put this upper circular band too high, so that it interferes with flexion of the knee.

Last of all the Scultetus bandage is fastened up, beginning at the heel; and the whole apparatus is moulded carefully to the malleoli and tibial condyles as it sets. As soon as it has become reasonably firm, the weights are removed, *and the stirrup applied for extension is cut and withdrawn;* neglect to remove it may cause a slough over the dorsum of the foot or over the heel. Usually the weights do not have to remain in place for more than 15 to 20 minutes from beginning to end of the procedure. The Scultetus bandage is removed in 24 to 36 hours, leaving the gypsum apparatus in place.

For the first day or two after the Delbet apparatus has been applied it is well to keep the limb elevated on pillows, and surrounded with ice bags, unless there has been at the time of the accident only insignificant injury of the soft parts. This precaution tends to prevent injurious swelling and the formation of blebs. In a few cases it may be necessary to remove the apparatus on account of swelling. Blebs appear not beneath the gypsum apparatus but on the exposed skin. They should be painted with iodine (3 per cent) or picric acid (2 per cent), punctured with a sterile knife, allowed to collapse, and dusted with sterile powder. Usually they may then be disregarded, and will give no further trouble. If the apparatus is not applied until swelling has developed, it is usually necessary to apply a second apparatus within a few days when subsidence of the swelling renders the first loose. Of 123 cases under Delbet's care, a second apparatus had to be applied in 68, a third in 28, and a fourth in a few cases; with only 20 patients was a single application of the apparatus sufficient.

The subsequent care and treatment of patients wearing the Delbet splint (Fig. 381) form an integral part of the treatment and must never be neglected. Within the first week or ten days, the patients are allowed to get up on crutches and are taught to walk. Putting the foot flat on the floor, they must dorsiflex the ankle and bend the knee at each step, thus bringing into function both joints, and preventing the atrophy of disuse or joint stiffness. This active mobilization has a singular tendency to promote rapidity of union in the fracture.

(2) Reduction *without continuous traction* usually requires a general anæsthetic, as the manœvres are very painful and the muscles in spastic contraction. Ether is better than nitrous oxide gas, because it secures more complete muscular relaxation. Those expert in the use of local anæsthesia may secure the same end by infiltration block of the leg. When muscular relaxation has been obtained, if the displacement is the usual one, with the food backward and outward,* the surgeon catches the patient's heel in the palm of his hand, and exerts steady firm traction downward and forward on the heel, at the same time making counterpressure backwards with his other hand on the front of the lower end of the tibia. In cases of posterior subluxation or complete dislocation (usually accompanied by a fracture of the posterior articular margin of the tibia), the foot during this traction will gradually resume its normal anteroposterior position beneath the leg. It then remains only to correct the lateral displacement of the foot by turning the heel strongly into adduction. The foot should be dorsiflexed to less than a right angle, so as to prevent recurrence of the posterior displacement; and should be overcorrected in adduction, so as to bring the lower fragment of the fibula close against the tibia by traction of the external lateral ligament.

Reduction having been obtained, retention in the fully corrected position is the next step. This is best secured by the use of moulded splints of plaster of Paris, as introduced by Stimson. The foot and leg as far as the knee are covered with flannel bandages while the plaster of Paris splints are being prepared. These are made by soaking a roller bandage about 10 cm. wide, and running it back and forth on itself as it is unwound (or by unwinding it on a reel), until a splint of suitable length (about 85 cm.) has been formed: two or three roller bandages of average length are required to make a splint of proper thickness (Fig. 382). The first splint is placed under the leg, from the lower thigh downward, and is continued forward along the sole as far as the toes, and is held snugly in place by a roller of flannel, *all* parts of the wet plaster being covered with the flannel so that the splint next

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*Fractures by *adduction* are reduced without much trouble by manual traction, usually without an anæsthetic.

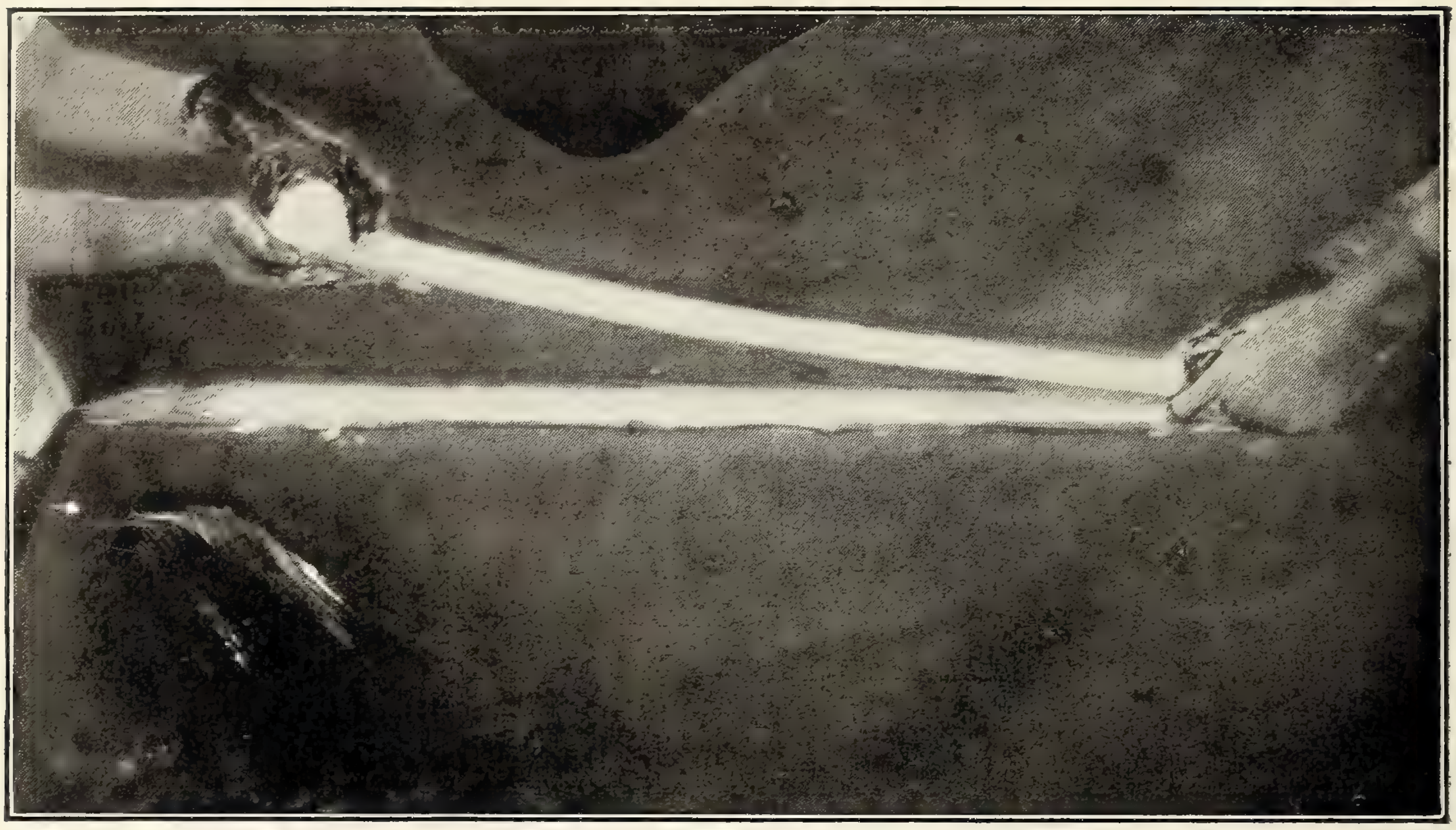

Fig. 382. Method of Making Gypsum Moulded Splints.

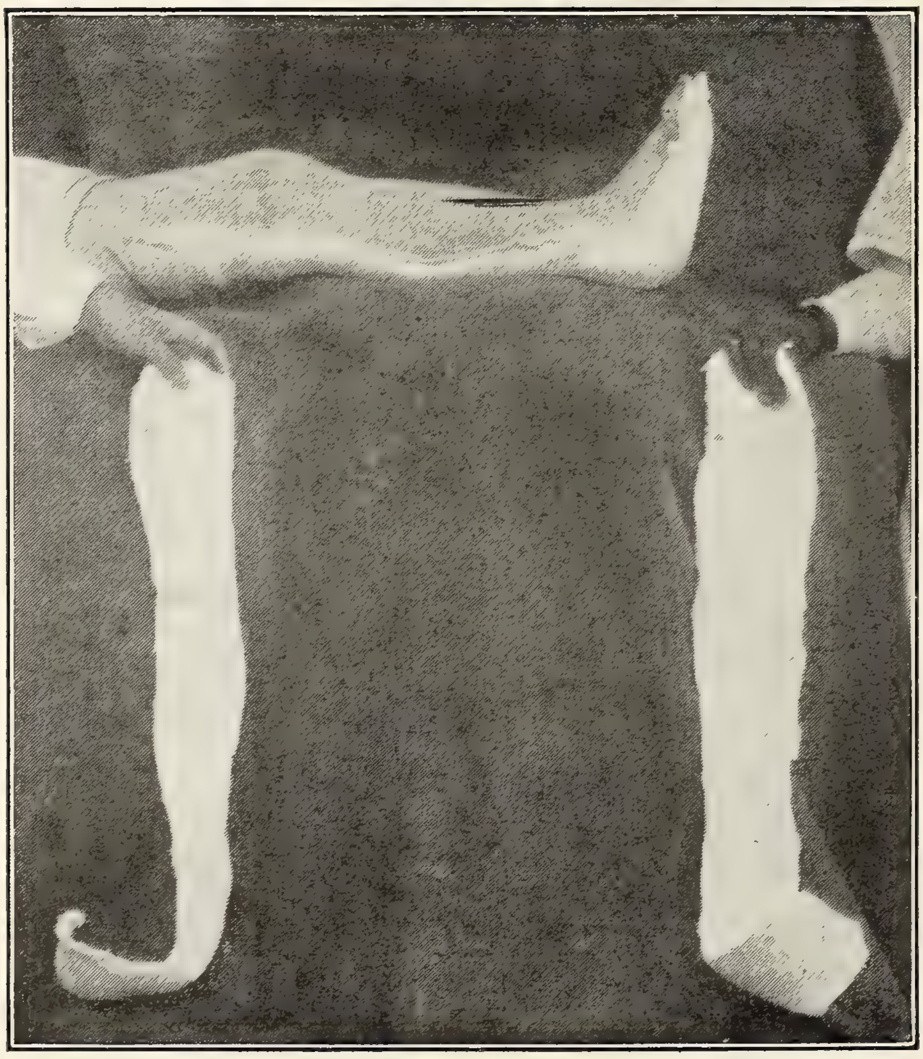

Fig. 383. Stimson Splints, showing the two lateral splints removed at the first dressing, while the limb rests undisturbed on the posterior splint.

to be applied will not adhere to the first. The heel should be lightly padded to prevent injurious pressure from the splint. The second splint is applied in a similar manner, beginning on the dorsum of the foot, thence crossing the sole and continuing up one side of the ankle and leg beyond the knee; and a third splint is applied around the foot and along the other side of the leg to a point above the knee. The great advantage of these moulded gypsum splints over the circular case is that they may be applied with much less disturbance of the leg, and hence with less likelihood of displacement of the fragments; and especially that the lateral splints may be removed easily once a week or oftener, to allow for proper care of the soft parts, without disturbing the posterior splint or the position of the fragments (Fig. 383). Injurious swelling is next to unknown, and fractures thus treated seldom give trouble from swelling during convalescence.

The accuracy of the reduction of ankle fractures should be controlled promptly by the X-Ray; and in case anatomical reposition of the fragments has not been secured, another attempt should be made at once. In *late reductions* manual force alone may not suffice, and recourse may be necessary to some form of orthopædic apparatus, such as the Thomas wrench, or to the equinus lever of the late Gwilym G. Davis (Figs. 384 and 385). I greatly prefer the lever. Sometimes subcutaneous tenotomy of the tendon of Achilles will aid in securing reduction, or in retaining it once it has been obtained. If even by these means complete reduction cannot be obtained, we must consider reduction by operative means. Operation should not be attempted until the primary swelling has subsided, nor until the skin is in perfectly healthy condition, for fear of infection; usually from the fifth to the tenth day is the best period. Nor should operation be

FIG. 384. EQUINUS-LEVER OF GWILYM G. DAVIS; the leather strap passes across the instep, and the cross bars beneath the ball of the foot. The operator, steadying the far end of the lever in his own axilla, has complete control of the patient's foot.

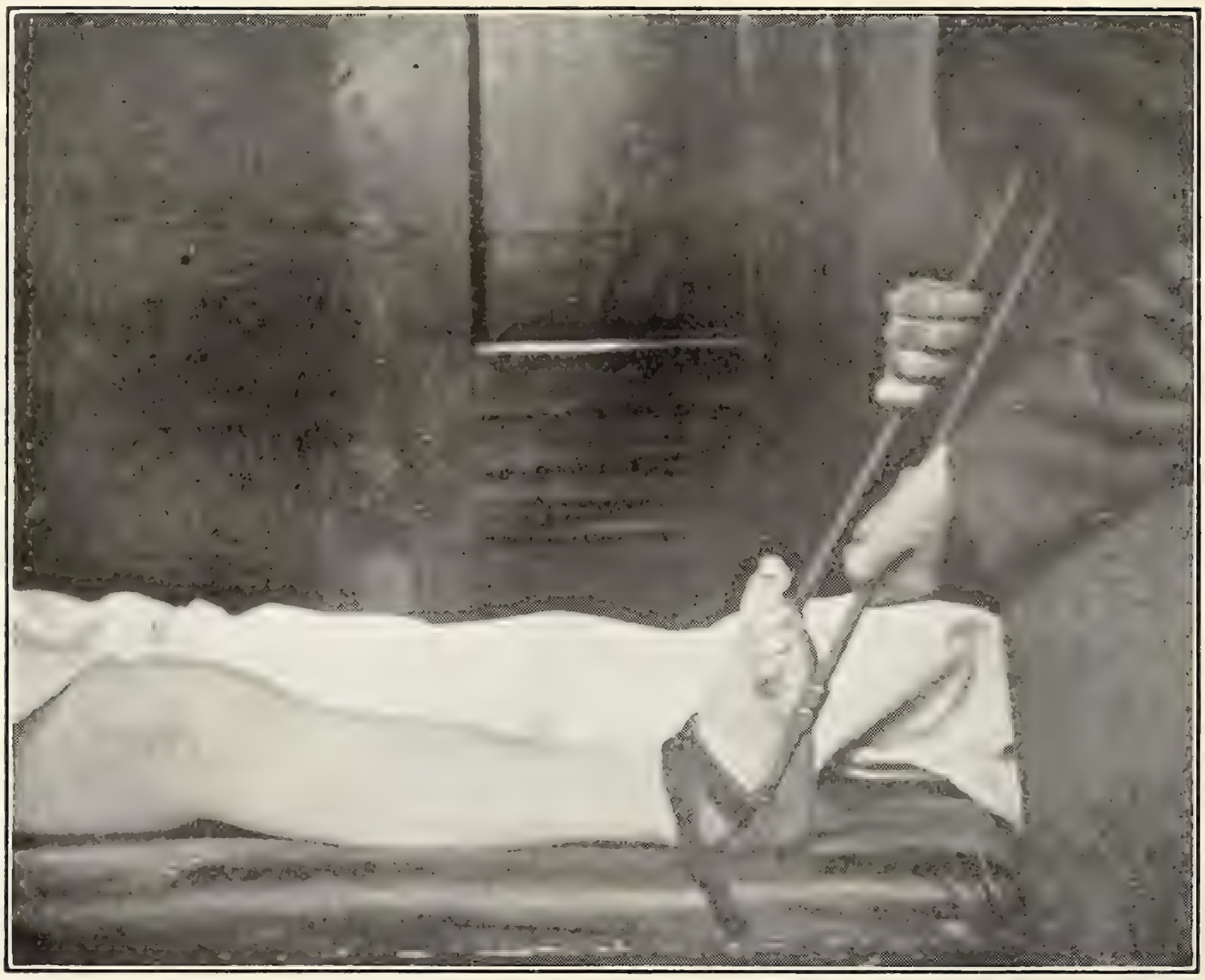

FIG. 385. EQUINUS-LEVER OF GWILYM G. DAVIS IN USE.

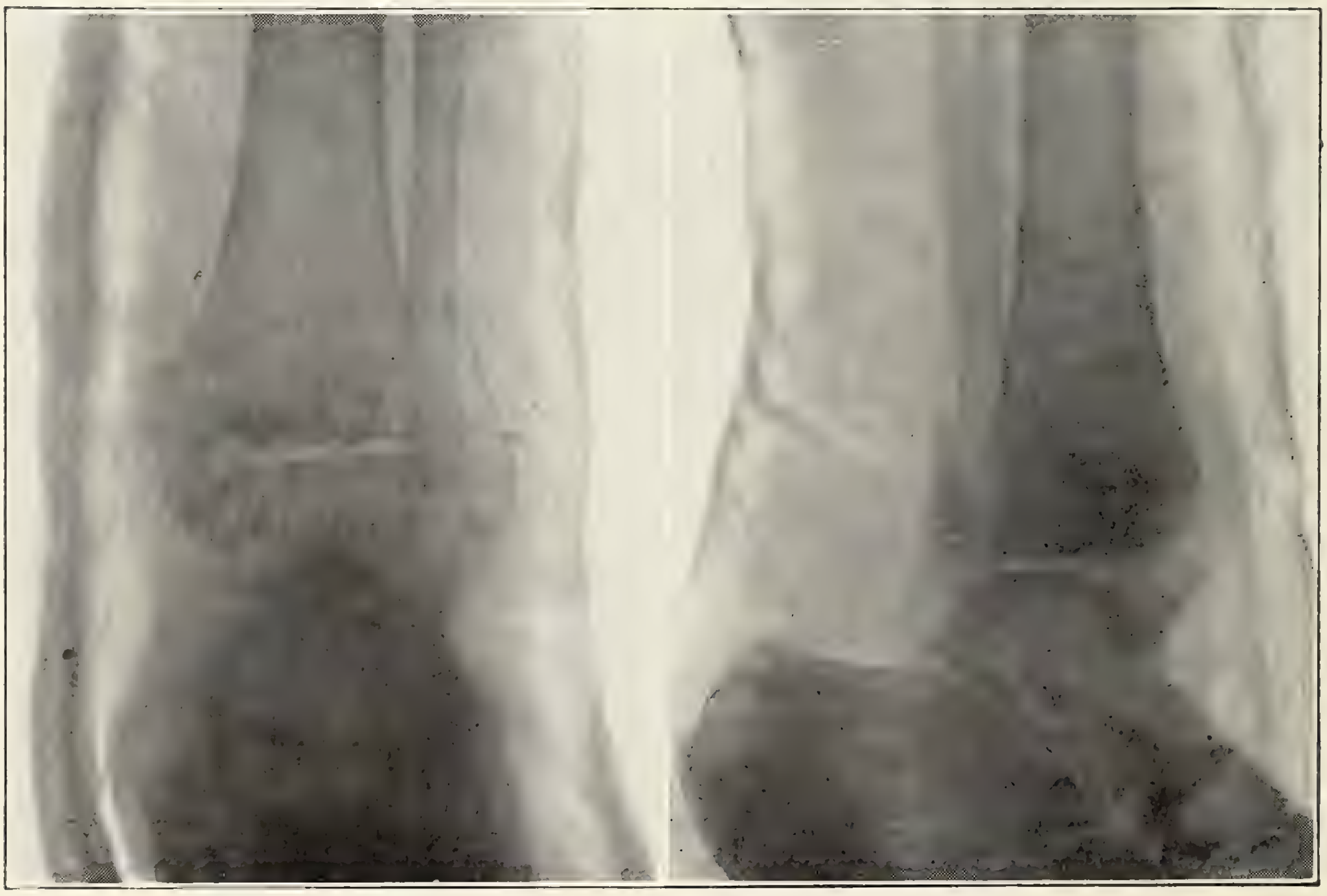

FIG. 386. CHARLES K., 52 YEARS. Jan. 13, 1917. Ankle fracture (A2x) after two attempts at reduction, the second attempt aided by the equinus-lever. Antero-posterior view: reduction not obtained. Same case, lateral view: failure to secure reduction.

attempted by any surgeon who has reason to doubt his ability to secure and to maintain, by its adoption, accurate anatomical reposition of the fragments; for if reduction is not secured at operation, it would have been better for his patient to have left the fracture unreduced.

In this *operation*, a liberal incision is made around the anterior and lower border of each malleolus, and the skin and superficial fascia are reflected backward until the fractured surfaces are exposed; these include the internal malleolus and the fibula, as well as the inferior tibiofibular joint. Interposed edges of fascia and periosteum are raised from the fractured surfaces, which are freshened with a curette; the tendon of the tibialis posticus and if necessary those of the peronei are temporarily removed from their grooves, the fracture is accurately reduced, and the fragments temporarily held in apposition by one of Lambotte's large clamps, while his self-boring screws are being inserted (Figs. 386,

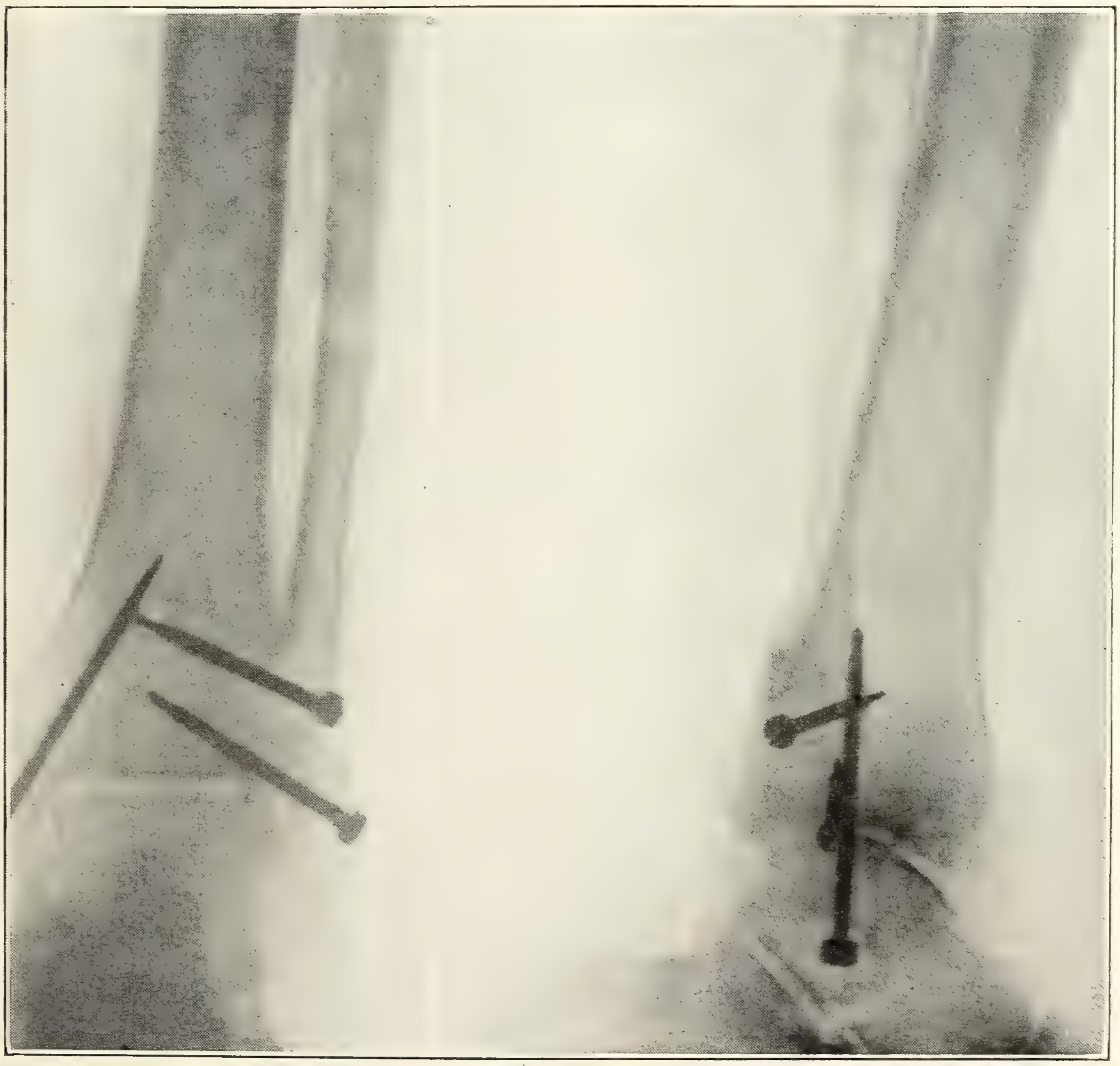

Fig. 387. Same Case as Fig. 386. Result of arthrotomy and screw fixation 11 days after injury. Out of work 13 weeks. Perfect anatomical and functional result. Screws still in place, over 7 years after operation.

387). The tendons being replaced and the deep fascia and skin sutured, an economical dressing is applied, and the fracture is treated as a recent simple fracture, except that protection by gypsum splints is not required for more than a couple of weeks. Weight-bearing, however, cannot be resumed any sooner than in cases in which open reduction has not been done.

Convalescent Care. If Delbet's apparatus has been used, the patient should be got out of bed by the end of the first week, and should be taught to walk, using crutches but bearing a considerable amount of weight on the fractured leg even from the first. If the apparatus becomes loose, another should be promptly applied. Usually by the end of the fifth week it may be dispensed with entirely.

If Stimson's splints have been used, they may be discarded one by one from the third to the sixth week, at which time the patient will be walking with crutches, and bearing all the weight he wishes on the injured leg.

When the use of a shoe is resumed, the surgeon should see that the inner edges of the sole and heel are raised, as already recommended.

In cases in which, for one reason or another, full reduction has not been secured, an orthopædic brace should be worn for about a year to prevent increase of the deformity. A suitable brace consists of two side-irons to below the knee, attached by a stirrup to a sole-plate built in the shoe, the side-irons being jointed not more than 5 cm. above the sole; and in cases tending to valgus deformity, with a pad over the internal malleolus.

When the soft parts have been properly cared for from the first, it is seldom necessary for the patient to be treated by baking, massage, or other forms of physiotherapy during convalescence.

The *average period of disability* in ankle fractures should not exceed 4½ months; in favorable cases the patient goes about his work without any disability in 12 or 13 weeks.

COLLES' FRACTURE

By Frederic J. Cotton, F.A.C.S.

Boston

Although it is over a century since this, the commonest of fractures, was fully and competently described, we have still no accepted or adequate method of handling it, and the average results in average hands are poor, while serious disability not uncommonly results. Despite the voluminous literature on the subject, little has been added, except for X-Ray details,[1] to the description by Colles in the remarkably compact little article published in the Edinburgh Medical Journal in 1814.

We know a little more about mechanism, and about repair process and complications, but the essential facts are still the same. The gist of it all is simply that this is a fracture across the radius just above the wrist, with backward displacement.

In the main, the fracture runs close to type. It is capable of complete repair, with restoration of normal contour and recovery of normal function; and any result less satisfactory is usually, though not quite always, due to an imperfection in our art or in its practice.

It has always seemed to me that with a lesion such as this our interest in academic detail is likely to become ridiculous unless it serves to make us competent in a very concrete and practical problem—a problem of simple mechanics, as will presently appear, far more than of abstract science. The purpose of this note is therefore to give first a concise account of our information, and then to emphasize the matters of mechanics, reduction, and care.

Causes. Commonly the fracture is caused by a fall on the palm of the outstretched hand, in which the impact comes at the base of the thumb. Less commonly the impact is on the ulnar side of the palm. In rare instances a like lesion may follow a fall on the dorsum of the hand, with the wrist flexed—an occurrence hard to understand, but apparently definitely shown to have happened.

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[1] Cf. *The Pathology of Fracture of the Lower Extremity of the Radius,* by F. J. Cotton, *Annals of Surgery,* August, 1900; also, Cotton, *Dislocations and Joint Fractures,* W. B. Saunders Co., Philadelphia, 1910, p. 320 ff.

Hyperextension may cause fracture, but not exactly of the Colles type; rather of the kind, now familiar, which results from being "kicked by a flivver" in cranking. For a long time it was erroneously believed that hyperextension produced the injury, even in ordinary falls. Hyperextension acts by "arrachement," evidently from the bone being torn off by force applied through the strong anterior ligament. This has often been done on the cadaver, and I have myself done it repeatedly.[1]

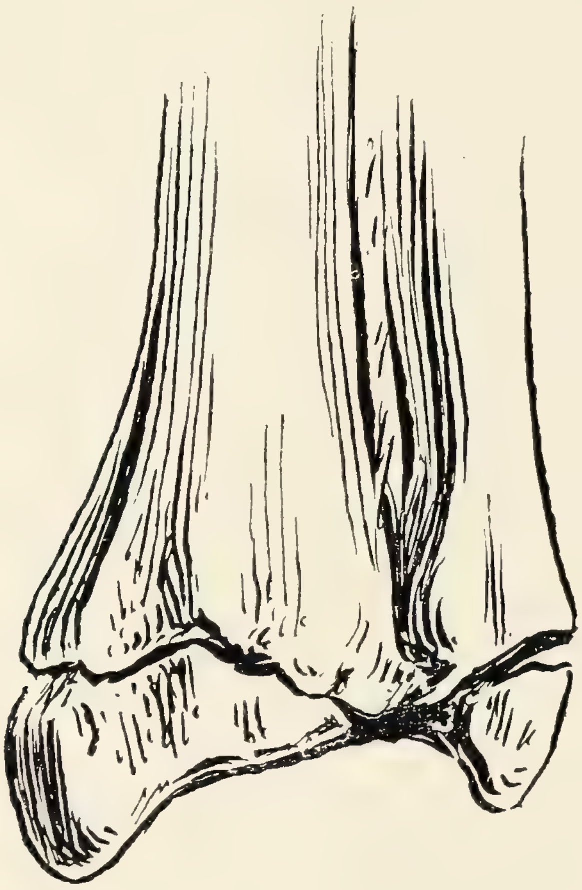

FIG. 388. FRACTURE OF RADIAL STYLOID. Warren Museum, Specimen 4631.

Crushing may, of course, split or crush the lower end of the radius, but this is not Colles' fracture.

Ordinarily the fall is on a partially extended hand. The force is of course in the weight of the body; but the mechanism is more easily understood if stated reversely, in terms of the impact on the hand. The blow strikes on the surface of the palm; the force acts to drive the hand up and back; and the bones give way transversely, or a bit obliquely, up and backward.

Relatively to the body it is the ulna, not the radius, that is the fixed member, and as the hand is driven up and back past the ulnar head, the head tears down and forward, the ligaments giving; very commonly the ligament-bearing styloid process also gives way. As this happens, the hand is carried up and back about the ulnar head as a fixed point, rotating in the direction of supination. The hand always goes back and into supination, and with it the distal fragment; and the distal fragment is always rotated with the hand up and backward, and into supination. But the force is not always sufficient to carry it up and back *clear* of the proximal portion of the radius, and hence one may have serious displacement even without the striking "silver fork" deformity.

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[1] *Experimental Colles Fracture, Journ. Boston Soc. Med. Sciences,* May, 1898; 11, 10, 171.

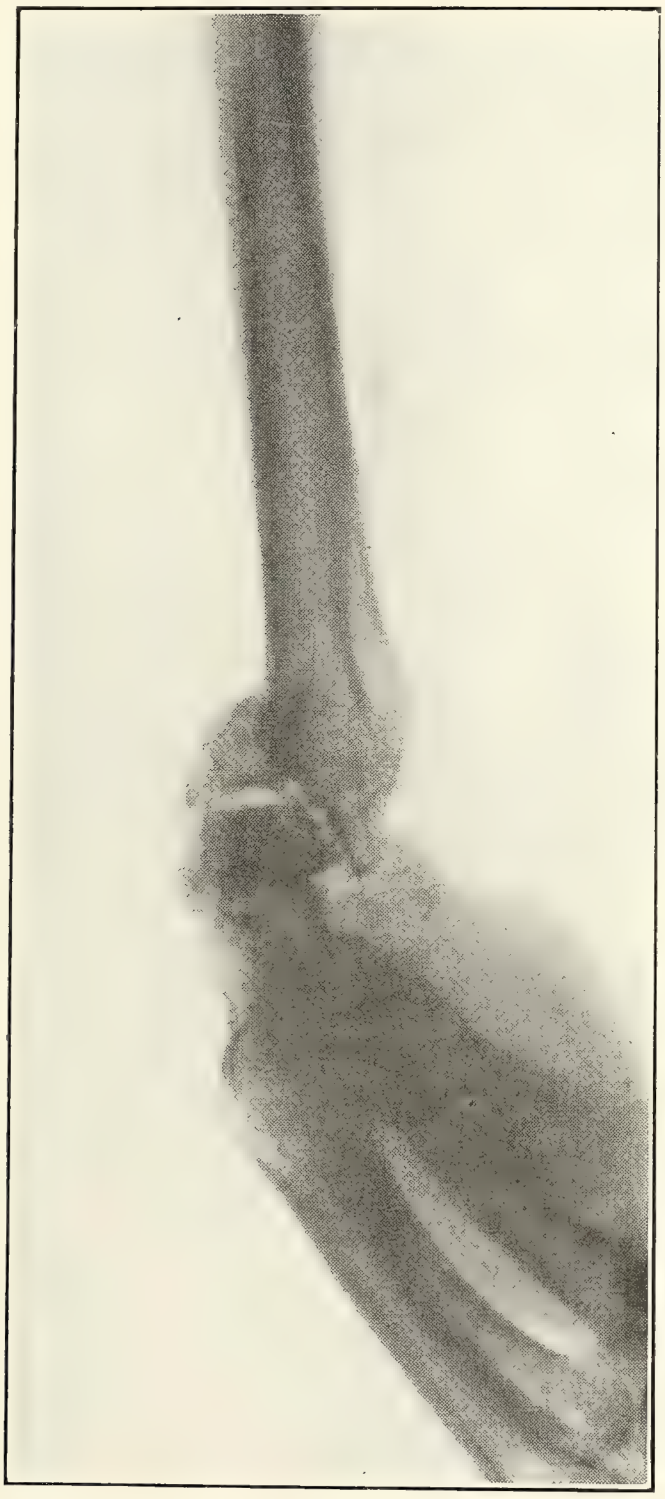

FIG. 389. BARTON'S FRACTURE. An untreated case, later reduced by open operation.

Lesions. A cross-break is found through the expanded lower end of the radius at a height usually of ½ to 1 inch (Colles said 1½ inches, but this is a bit too high), commonly running somewhat obliquely up and backward. Great obliquity is unusual. Rarely the obliquity is reversed, this occurring usually, though not always, in cases where the back of the hand seems to have been struck.

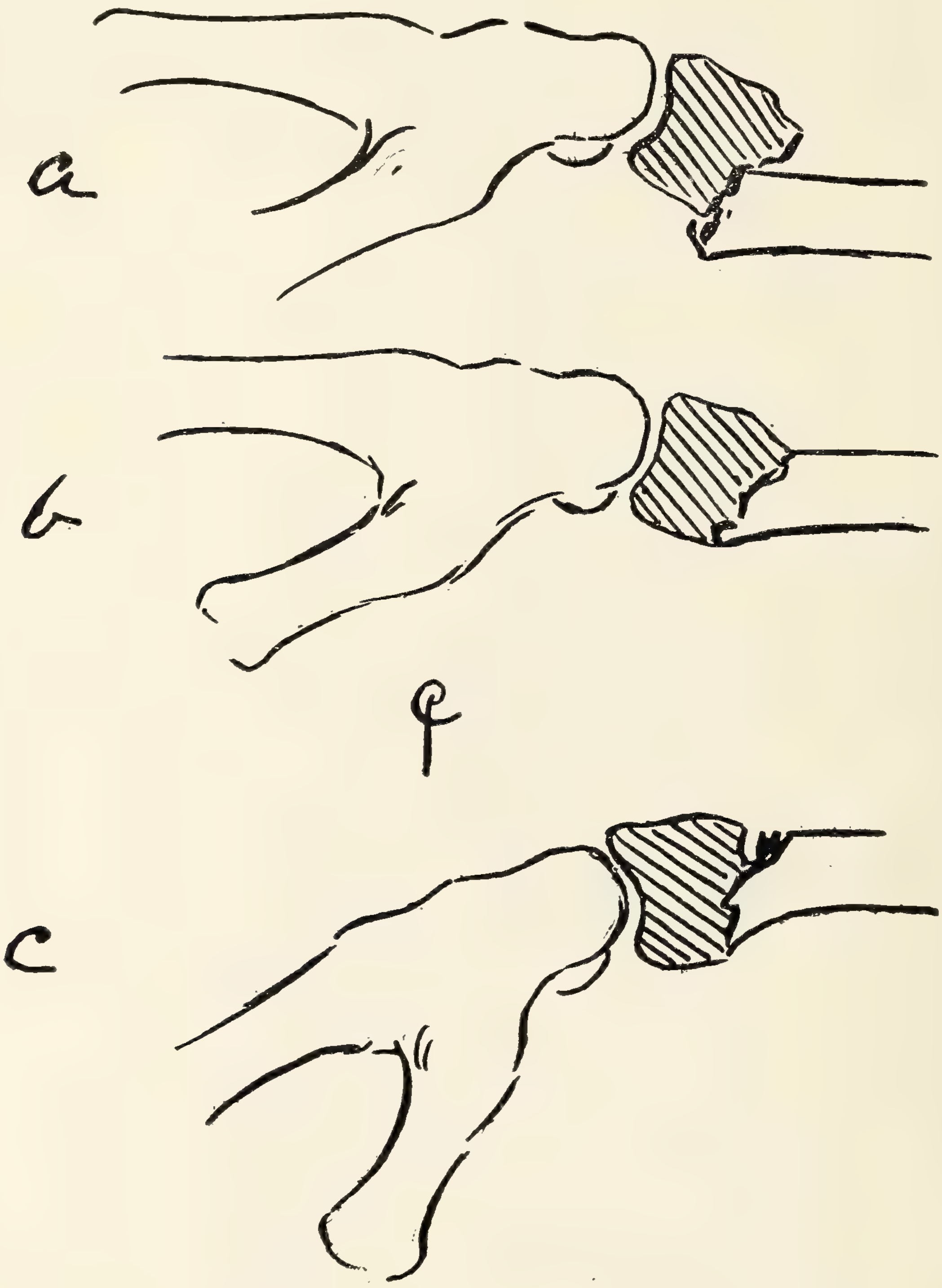

FIG. 390. *a.* DISPLACEMENT BACKWARD. *b.* ROCKING BACKWARD WITHOUT TOTAL DISPLACEMENT. *c.* CORRECTION OF B, showing gap left where bone was crushed by the "impaction." (*Boston Medical & Surgical Journal.*)

There is often comminution, but separation of the split-off fragments is usually slight, if present at all. In nearly all cases, the pattern of comminution seems to approximate one of the two patterns shown in the illustrations, Fig. 394. Extreme comminution is rare.

It is not rare, especially with older bones, to observe crushing or crumpling at the back edge as well as a cross-break, with or without splitting.

In the automobile fractures, latterly so familiar, we find a break lower and more accurately transverse, corresponding very closely to what is obtained in cadaver experiment by hyperextension, and indeed it is most probable that the fracture results from hyperextension in these "backfire" accidents, and that the mechanism is one of true "arrachement." In this type we rarely see any splitting of the fragment or definite crumpling at the edge. Except for these two differences, and for the greater frequency of complete fracture without essential displacement—and hence with less damage to soft parts—these injuries pretty exactly duplicate Colles' fracture as it results from a fall.

In other automobile cases we see a fracture running from the mid-joint toward and slightly upward, really approximating a fracture of the radial styloid. Such a fracture is not necessarily from an automobile accident; in fact, the best specimen extant (Figure 388) long antedates the automobile. Probably the lesion results from an abduction strain added to hyperextension.

Another not dissimilar type shows greater obliquity usually with sharp *outward* displacement. This probably results from a fall in which the impact comes on the closed hand or on the "heel of the hand" at the ulnar side.

Fracture of the radial styloid alone, with or without scaphoid fracture, is a separate type, and not an extraordinarily rare one.

"Reversed" Colles' fracture shows anterior displacement.[1] From Roberts' admirable monograph[2] one would gather that it is not uncommon, but in practice it seems very rare indeed.

Barton's fracture is so called from a description written long ago by Rhea Barton.[3] Although he was probably writing erroneously of Colles' fracture, he nevertheless described the breaking away of only the back end of the radius, a lesion which occurs in rare instances as a variant of the typical fracture (Figure 389). "Reversed Barton's" is, as the name implies, merely a variant of the "reversed Colles." It has been seen only once by the writer, and is hardly of interest except to the collector of oddities.

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[1] There are rare instances of anterior sloping of the fracture face without the forward displacement which should be present in "reversed Colles."

[2] J. B. Roberts, *A Clinical, Pathological, and Experimental Study of Fractures of the Lower End of the Radius, with Displacement of the Carpal Fragment toward the Flexor on Anterior Surface of the Wrist,* P. Blakiston's Son and Co., 1897.

[3] Barton, *Medical Examiner,* Philadelphia, 1838, p. 365.

Splitting away of the ulnar face of the radius occurs in some instances.

Extensive comminution of the whole lower end of the radius, in no intelligible form or pattern, is occasionally seen.

With young patients, separation of the radial epiphysis is seen commonly enough, either clean or, less frequently, with a scale of diaphysis going with it. The epiphysis is rotated and displaced upward and backward, just as in the fracture. Separation of the ulnar epiphysis may be found associated with this type, but more commonly the associated lesions are those of ligament-tearing, with or without avulsion of the ulnar styloid, just as in Colles' fracture proper.

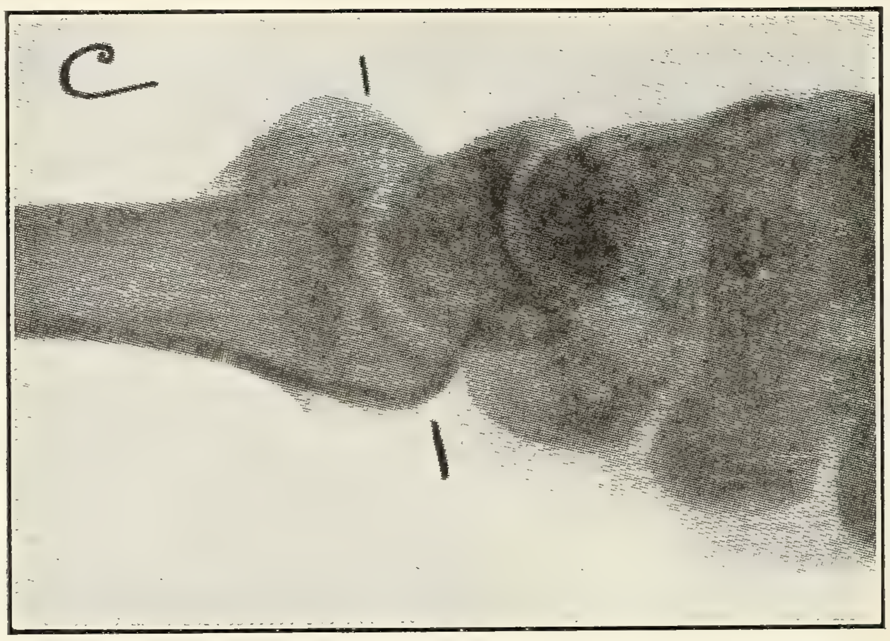

FIG. 391. TILTING OF JOINT SURFACE IN UNREDUCED COLLES' FRACTURE. The slope here about 15 degrees backward, instead of the normal 15 degrees forward.

In young children, oddly, a fracture clear above the epiphyseal line, a little higher than the Colles type, seems to be quite as common as the epiphyseal lesion, and with small children a fall on the hand commonly results, neither in Colles' fracture nor in epiphyseal damage, but in a greenstick fracture of *both* bones hard above the wrist or perhaps an inch and a half higher up.

Fracture of the ulnar styloid is very common. Broken oftener, no doubt, by ligament-pull than by impact, the styloid may give way at any point. Most often it does so near its base, with a fracture line transverse or moderately oblique, usually up and inward.

Fracture of the head or neck of the ulna, though often talked about, is extremely rare. In the writer's opinion the observers who mention it as frequent are simply in error, though cases may of course occur.

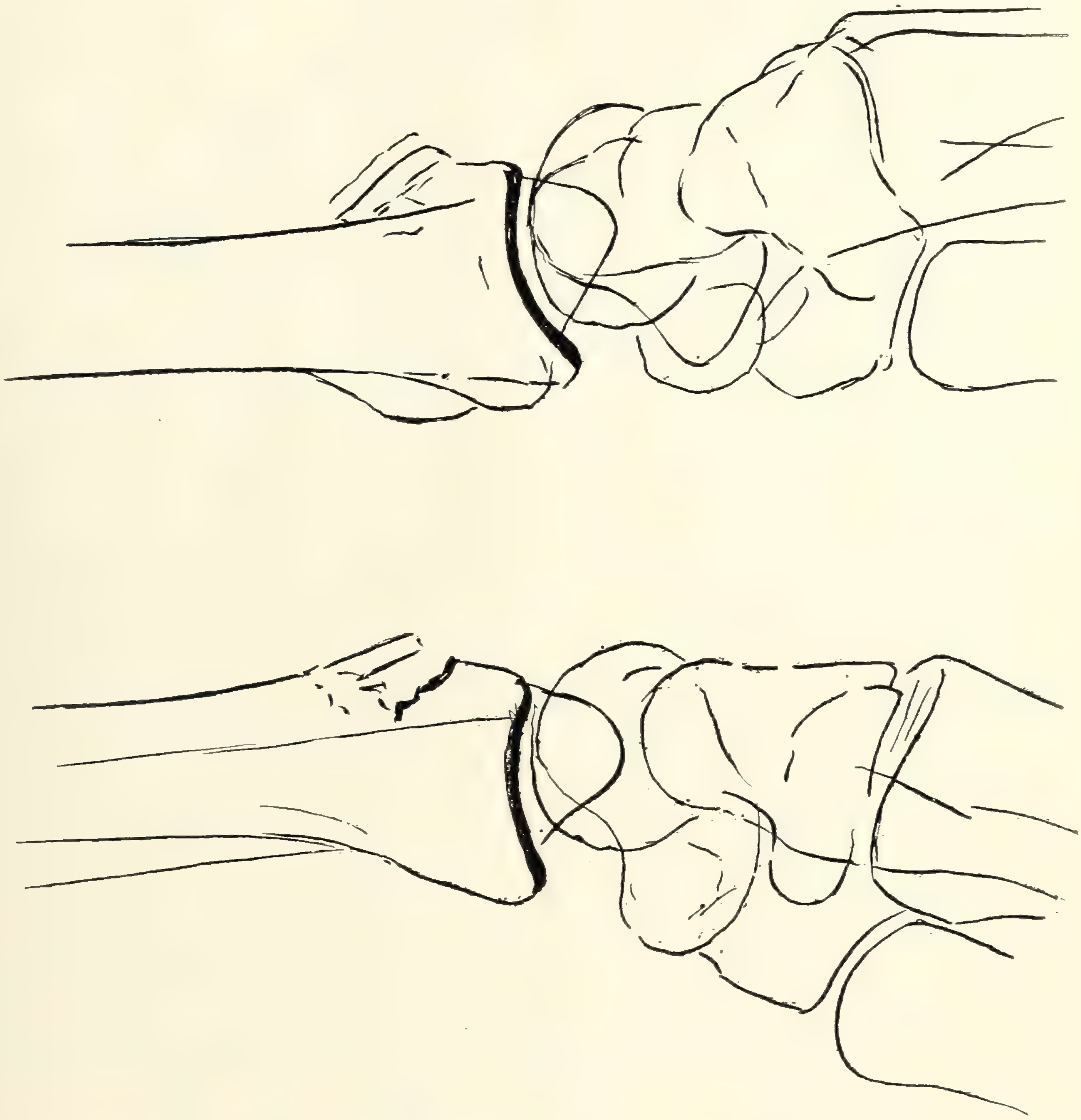

FIG. 392. BEFORE REDUCTION. Jan 23, 1918. AFTER REDUCTION. 9 days. Note the change in plane of the radial joint surfaces.

The writer has seen it only once, in a compound case, and then in a breaking away of the articular surface solely.

The details of ligament damage of course vary; but fairly constantly, in the cases with sharp displacement, one has, and must have, three points of damage:

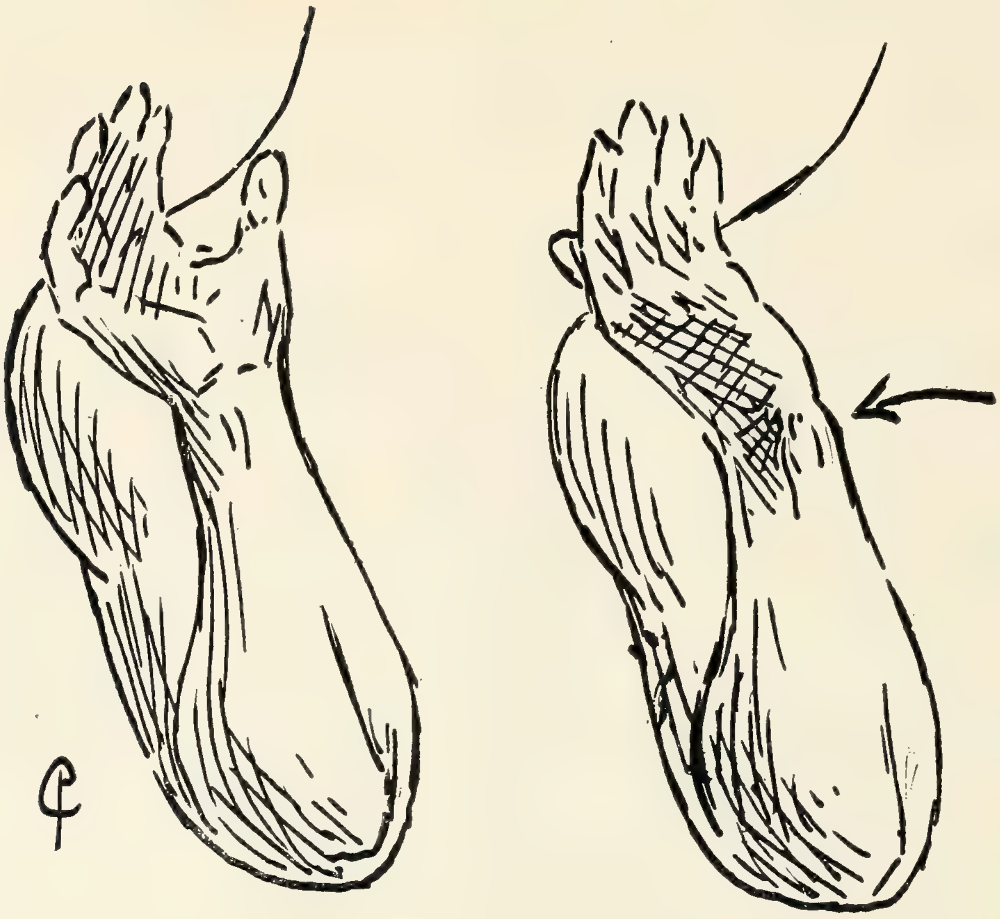

FIG. 393. POSITION IN WHICH THE LOOSE ULNA IS BEST SEEN. As the hand rolls back in supination, one easily sees the forward excursion of the ulnar head about which it rotates, and can estimate its degree of looseness.

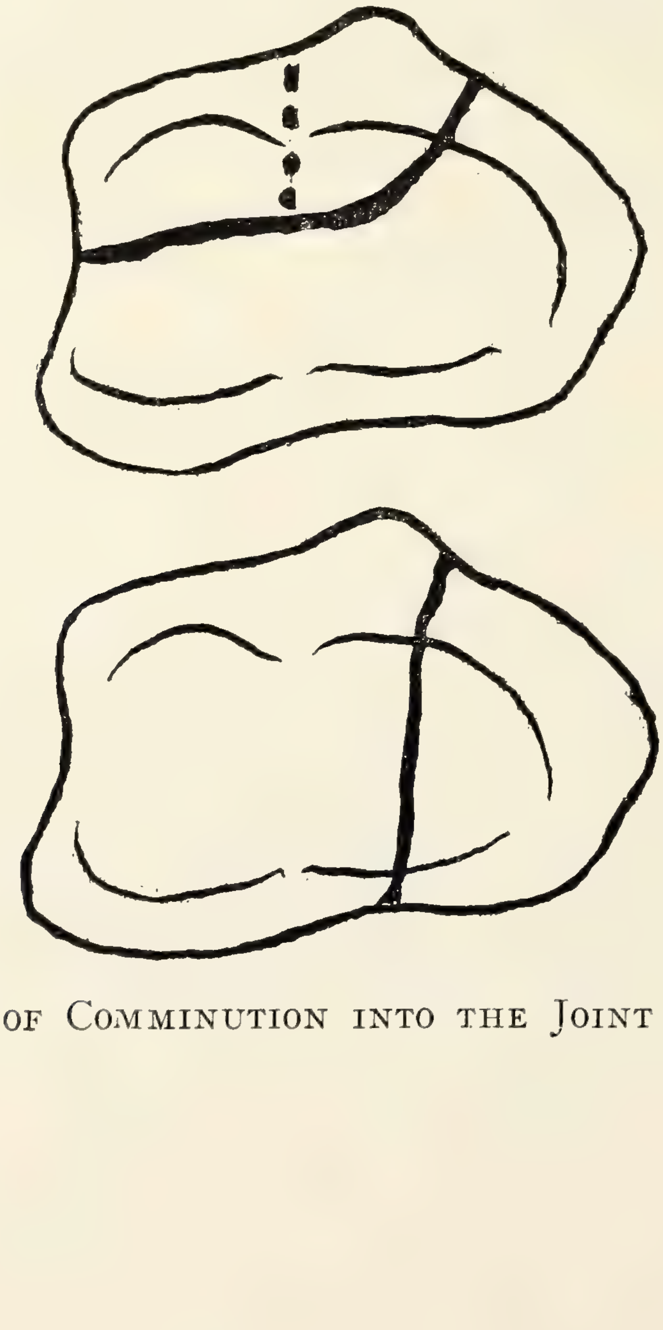

FIG. 394. FORMS OF COMMINUTION INTO THE JOINT SURFACE THAT OCCUR COMMONLY.

First, tearing of the lateral ligament between ulna and carpus.

Second, tearing of the triangular fibro-cartilage between the ulnar styloid at its base and the near edge of the radius (it should be remembered that there is no joint between ulna and carpus).

Third, tearing of the anterior and posterior ligaments between radius and ulna.

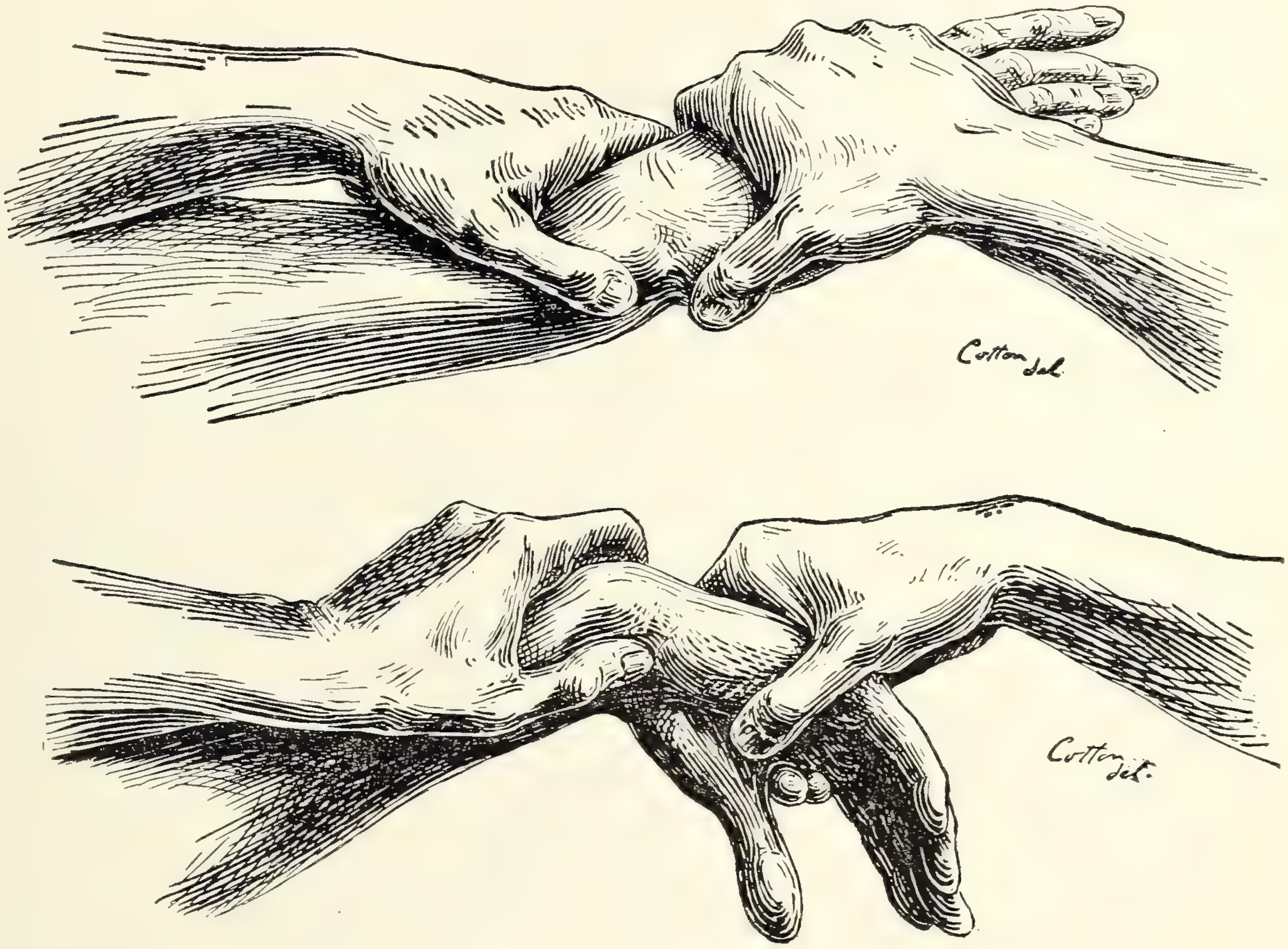

Fig. 395. First Traction and Rocking, with the hand a little extended (backward) so as to free the displaced radial fragment and the dislocated ulna; then, with the thumb under the ulna, making it a fixed fulcrum, drag the hand down into flexion and pronation, keeping up traction combined with the flexion and rotation. (*Boston Medical & Surgical Journal.*)

One must not forget that there is a definite radio-ulnar joint and that in every Colles' fracture the surfaces of the joint are twisted on each other if not actually torn apart. It is the extent of the ripping apart about the ulna, occurring *not rarely but typically,* which is often lost sight of; and it is this damage which is in fact responsible for most of the permanent disabilities.

Compound Fractures. These are rare. Almost invariably the wound is caused by a tearing through of the ulnar head, the spadelike edge left by the breaking away of the ulnar styloid furnishing an excellent cutting blade.

I have seen wrist fractures compound over the radius in front, or over either bone behind, but they were not true Colles' fractures.

Injuries to vessels are rare. There is a specimen preserved of a case in which the sharp lower edge of the upper fragment cut the artery, with resultant gangrene, etc.[1] The writer has once seen the radial artery caught in the impaction. It was freed in the reduction, with return of pulsation; presently it became thrombosed, but without any serious consequences and without obvious symptoms. The writer has also had one compound case, and seen another, in which the ulnar artery was torn over the protruding head. This causes little bleeding, since the artery is crushed off, and not cut.

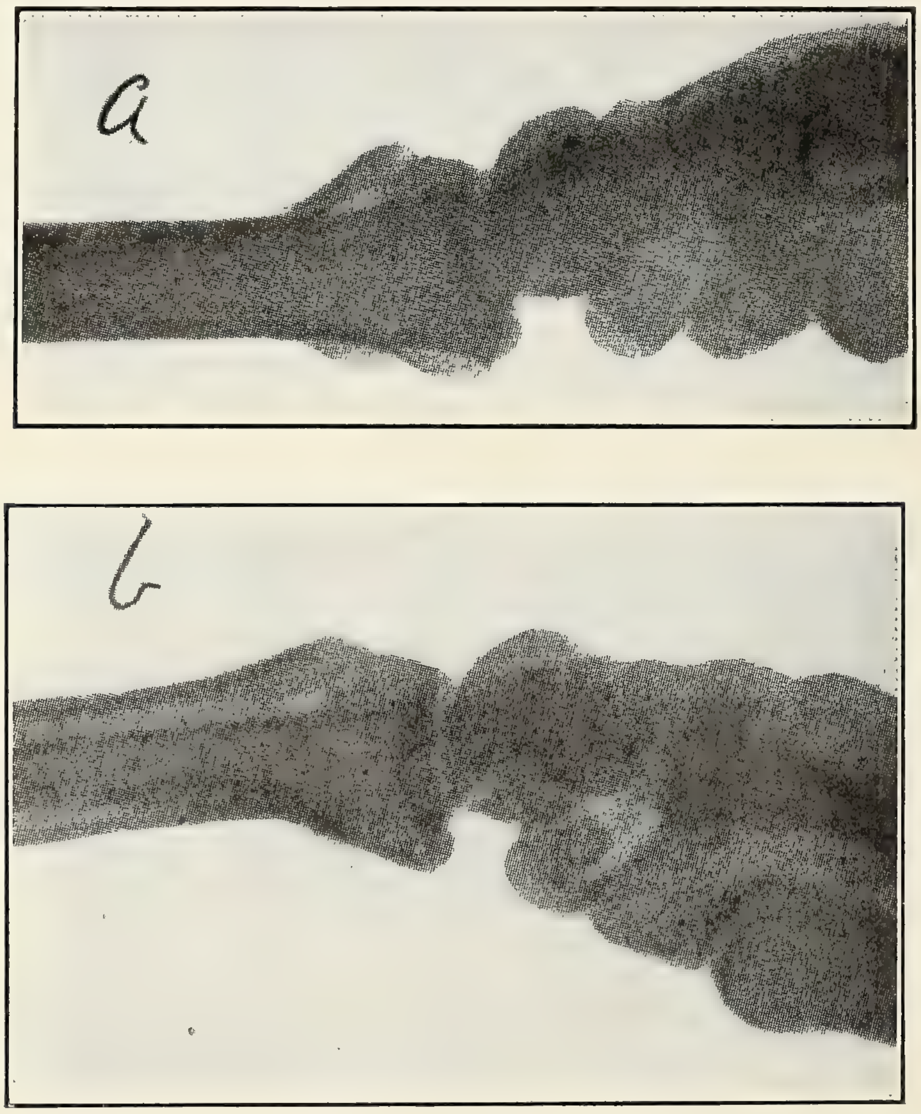

FIG. 396. *a.* BEFORE REDUCTION. *b.* AFTER REDUCTION. In this case splints were used, not plaster. (*Boston Medical & Surgical Journal.*)

Vein injuries are common but seem never to be serious. No really important veins lie in this region.

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[1] Warren Museum, Harvard Medical School, Specimen 8117.

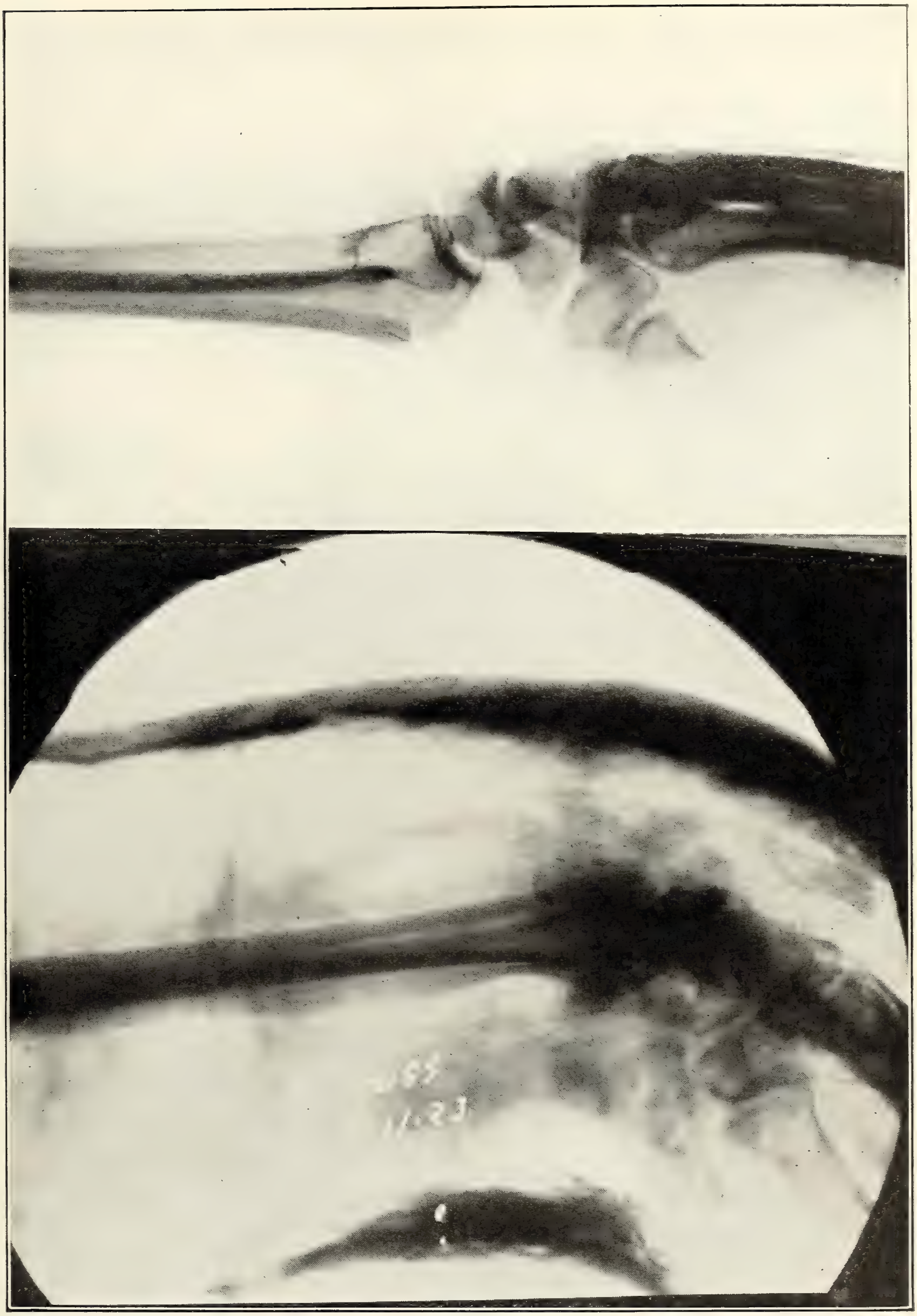

Fig. 397. Before Reduction and After Reduction, held in flexion in plaster of Paris. Position maintained by flexion, without pressure.

Nerve injuries are commoner. I have seen the ulnar nerve once torn across and once severely contused, both times in compound cases; and with no great rarity it is sufficiently contused to cause temporary dulling of sensation in the last two fingers. Damage to the median nerve I have not seen, further than a temporary contusion. Damage to the radial nerve (at this level a sensory nerve only) is rare, but I have had two cases in which the posterior branch of the radial was caught in the impaction and freed in the reduction, recovering after a considerable interval, and another case in which the anterior branch was caught in the smash, along with the radial artery. The pain suffered until this fracture was reduced was very severe. The final result was complete recovery.

No mention is made at this point of the common nerve lesions due to tension and irritation long after the fracture in cases imperfectly reduced and treated.

Tendon damage must be a rare curiosity if it ever occurs at all. Tendon sheath damage, long the excuse for stiff fingers, is probably negligible, though it cannot be disproved.

Effusion, very prompt in the sheaths of the long extensor of the thumb, where it and the carpal extensors have a common (short) sheath, is frequent but apparently unimportant. The absorption is too rapid for us to suppose that the effusion is blood.

Complications. Swelling occurs, of course, but is rarely serious unless aggravated by improper bandaging; it results partly from hæmorrhage, partly from reaction to trauma. Blebs rarely appear—more rarely than we should expect from the frequency of marked swelling, etc.

The only serious complication to be looked for is the so-called traumatic arthritis. This occurs, not only in known arthritics, nor even most often in them, but in individuals supposedly normal. It is characterized clinically by pain, swelling, stiffness, local heat, and sometimes by localized joint swellings, not only in the near-by joint but even oftener in the carpal, metacarpophalangeal, and phalangeal joints; and the confirmatory X-Ray shows an astonishingly intense osteoporosis, involving usually the whole hand and the forearm bones a bit above the fracture. Joint changes are slight; often there are none that we can be sure of, though now and then changes of a hypertrophic type occur.

In these cases complete recovery may be expected, with rare minor adhesions, but progress to recovery is very slow. The repair of the fracture is distinctly retarded, and at least twice I have seen progressive recurrence of a reduced backward tilting, some weeks after reduction, caused by absorption of bone during the osteoporotic stage.

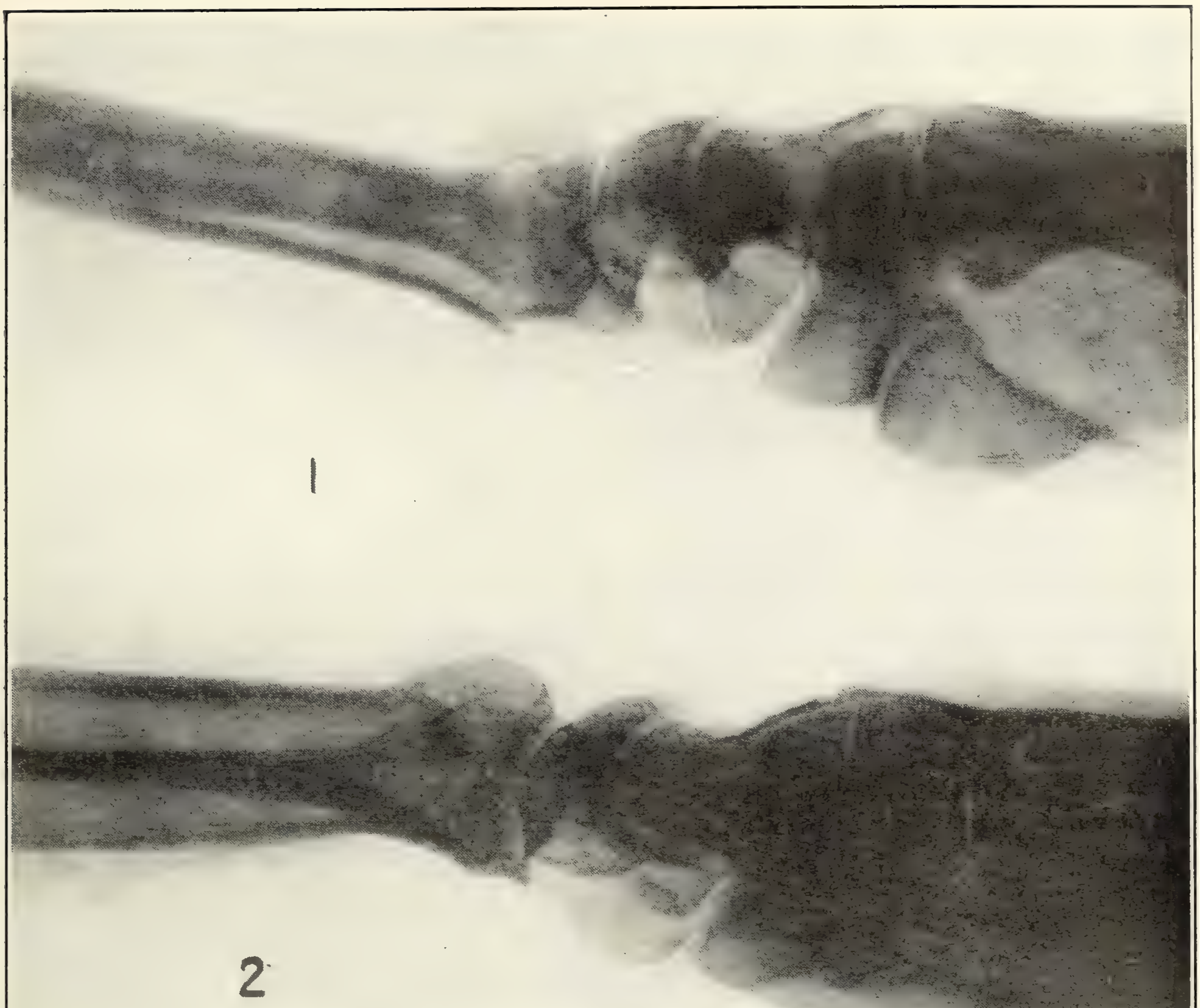

FIG. 398. 1. BEFORE REDUCTION. 2 and 3. AFTER—Reduction not by me but my assistant. Method proper, result practically perfect.

Symptoms. In cases of displacement the fracture is, for most people, very painful. The pain disappears in the main on proper reduction, and if the reduction is prompt as well as adequate the injury will commonly become painless.

One must beware of expecting helplessness merely because pain is present. Many a plucky man or woman who has found that the injured hand is not helpless has proceeded on the theory of a sprain. The fact is that a Colles' fracture, if not greatly displaced or if properly replaced, is no great handicap *mechanically*. A good general rule is that there are no sprains of the wrist unless a *good* skiagraph says so.

Treatment. Prompt reduction should be effected when the diagnosis is made. A competent surgeon need not wait for the X-Ray in most cases. The earlier the reduction, the quicker the convalescence.

The diagnostic doubt is between Colles' fracture and carpal injuries. If present, silver-fork deformity—change in relation of level of radial and ulnar styloids—or deformity of the radius with loss of the arch in front and with the presence of a ledge behind (A. T. Cabot's sign), should remove any question in a fresh case. Cases already not quite fresh can wait a bit for the X-Ray without further damage from the delay.

For reduction, countless methods have been proposed; the essential thing in all of them is traction down, or down and back to disengage fragments—traction down with a shove forward to reduce the backward displacement. Add to this the circumduction devised by Moore[1] of Rochester, to clear the entanglement of the broken ulna in the ligaments, and I believe we have covered nearly all the mechanics of reduction.

Most of the work has been done in devising splints, though they are secondary in importance to really good reduction, as was shown long ago by Moore and more recently by Roberts and others. Any mention of splints without favoritism would be historical review only. Suffice it to recall three types—the Nelaton, the Carr-Nelson, and the flat cut-out. The Nelaton "pistol splint" is, I think, no longer used. It surely has no place. The Carr-Nelson type, or the modern adaptations of Levis and Parker, are good if one remembers that the splint can only hold what has been gained already. The flat splints are good, but only if well padded.

Putting these considerations aside for the moment, the writer is going to say what he has found to be true as to the best reduction and the proper maintenance of a reduction once attained.

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[1] *New York Medical Record,* 1880, xlii, 305.

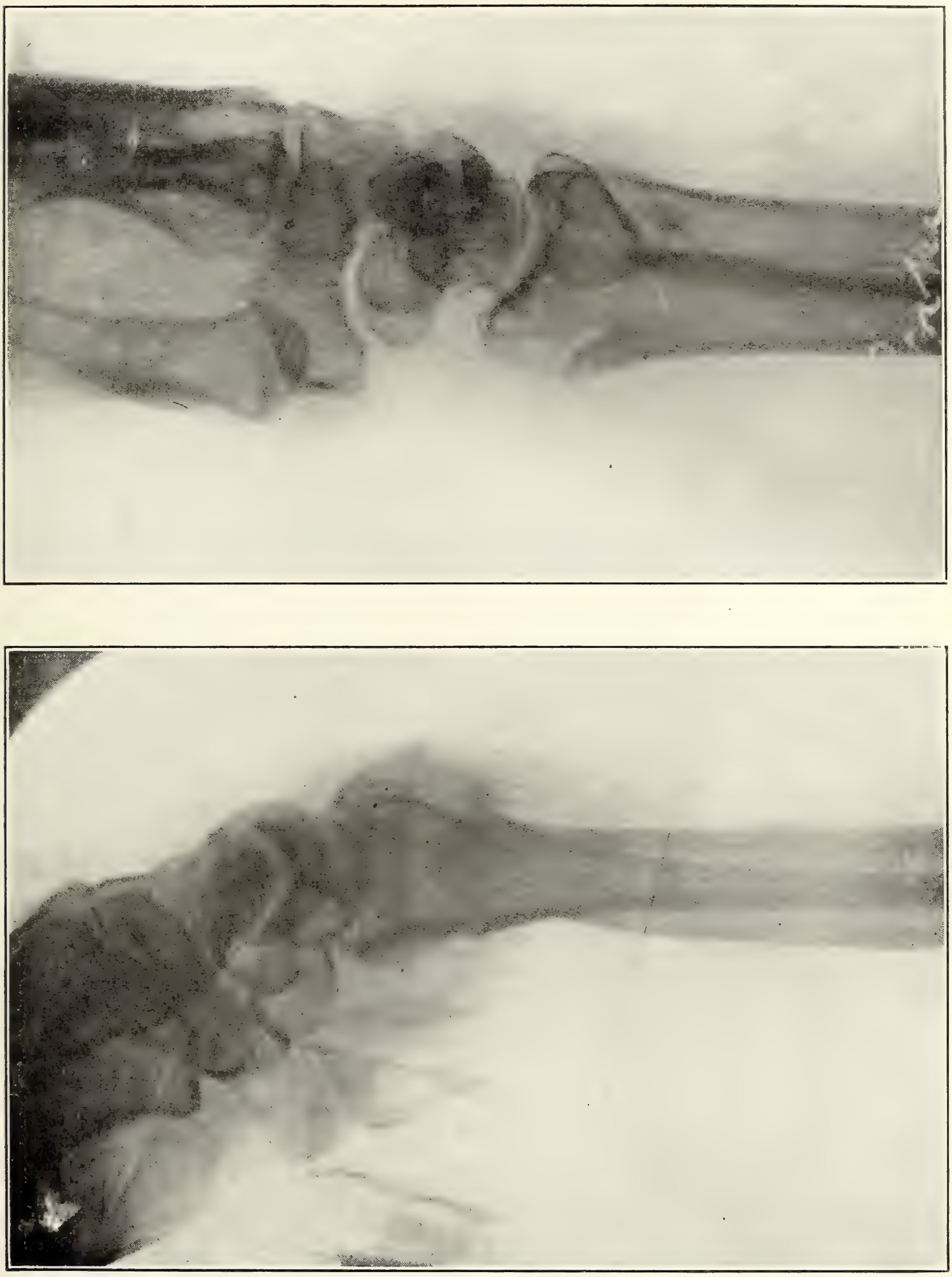

Fig. 399. *a.* Three Weeks After Fracture and Alleged Reduction. *b.* After Reduction with "Thomas" Wrench. Shown as held in flexion on splint. (*Boston Medical & Surgical Journal.*)

With regard to reduction, we have a break in which the hand and lower fragment have been driven back and up and over into supination, about the ulnar head as a fixed point, and also thrown into rotation in the sense of hyperextension. With ligaments gone, it is theoretically simple to carry the fractured bone back along the same path—down, forward, and into pronation with flexion superadded.

A rather exhaustive overhauling of final results has shown, moreover, that disabilities[1] result from backward rotation of the fragment rather than from backward displacement *in toto,* and particularly from insufficient fixation of the ulna in its bed—this in turn being due to a distortion of the bed on the radius in which the ulnar head should lie. If one analyzes the argument from these disabilities (which chanced to be the way in which the writer worked), it leads to the same conclusion as the theory of returning the displaced fragment by the route through which it came out.

The form of reduction based on these considerations is as follows: (1) Preliminary traction to pull the fragment over the broken end of the shaft; (2) pronation about the ulna; (3) flexion. This amounts to (1) disengagement by hyperextension-traction, and (2) a combined movement of traction, pronation, and flexion about the ulna, held as a fixed point. Figure 395 will perhaps make this clear.

With reduction accomplished, the question of holding comes next. For a time the writer used splints as shown in Figure 399, heavily padded. But certain troubles developed. First, in elderly bones with a bit of splintering behind, there may be a return of the backward rocking of the fragment under muscle pull. Second, one can hold this only in flexion. Third, flexion proved curiously free from the difficulties one had expected in getting back motion, etc. Therefore, plaster applied in flexion, split along the ulnar side to avoid even the chance of constriction, has become the writer's routine.

Since the publication of this method in the *Boston Medical and Surgical Journal,* December 4, 1919, pp. 651-656, it has been adopted by many other practitioners, apparently with results similar to our own, and certainly better than those secured by other methods. Since the adoption of the method, the writer's own results have nearly all been perfect, most of the patients recovering normal function without even the loss of prominence of the ulnar head, which is otherwise so nearly universal.

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[1] Apart from the stiffening of disuse or arthritis. Lax ligaments occur, but they have healed lax *because* of this lax position.

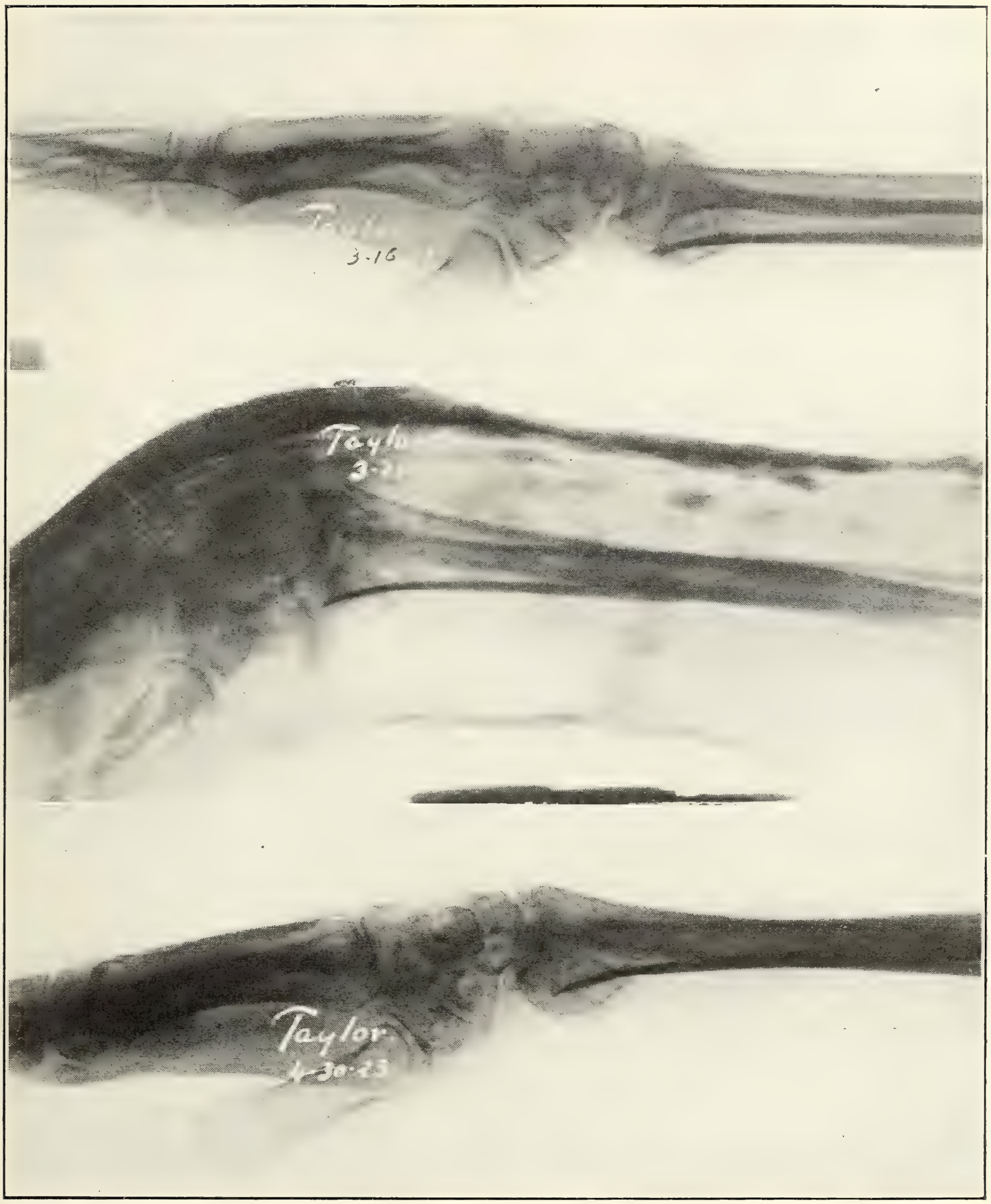

FIG. 400. FOUR WEEKS AFTER ALLEGED REDUCTION. Marked "arthritic" reaction. 2. AFTER RE-REDUCTION WITH "THOMAS" WRENCH. 3. SIX WEEKS LATER. Arthritis persisting though it cleaned up later with almost entire recovery of flexibility after a year. The anatomical result nearly perfect—perfect so far as the a. p. contour is concerned. No method as yet gives absolute results in relation to the *abduction* deformity.

After-Treatment. Motion of the fingers should be practiced from the beginning. Fixation in flexion should be kept up for from three days to three weeks according to the case (X-Rays checking), and should be longest in cases with a large chance of recollapse of the posterior shell. Then protection on a straight back splint should be con-

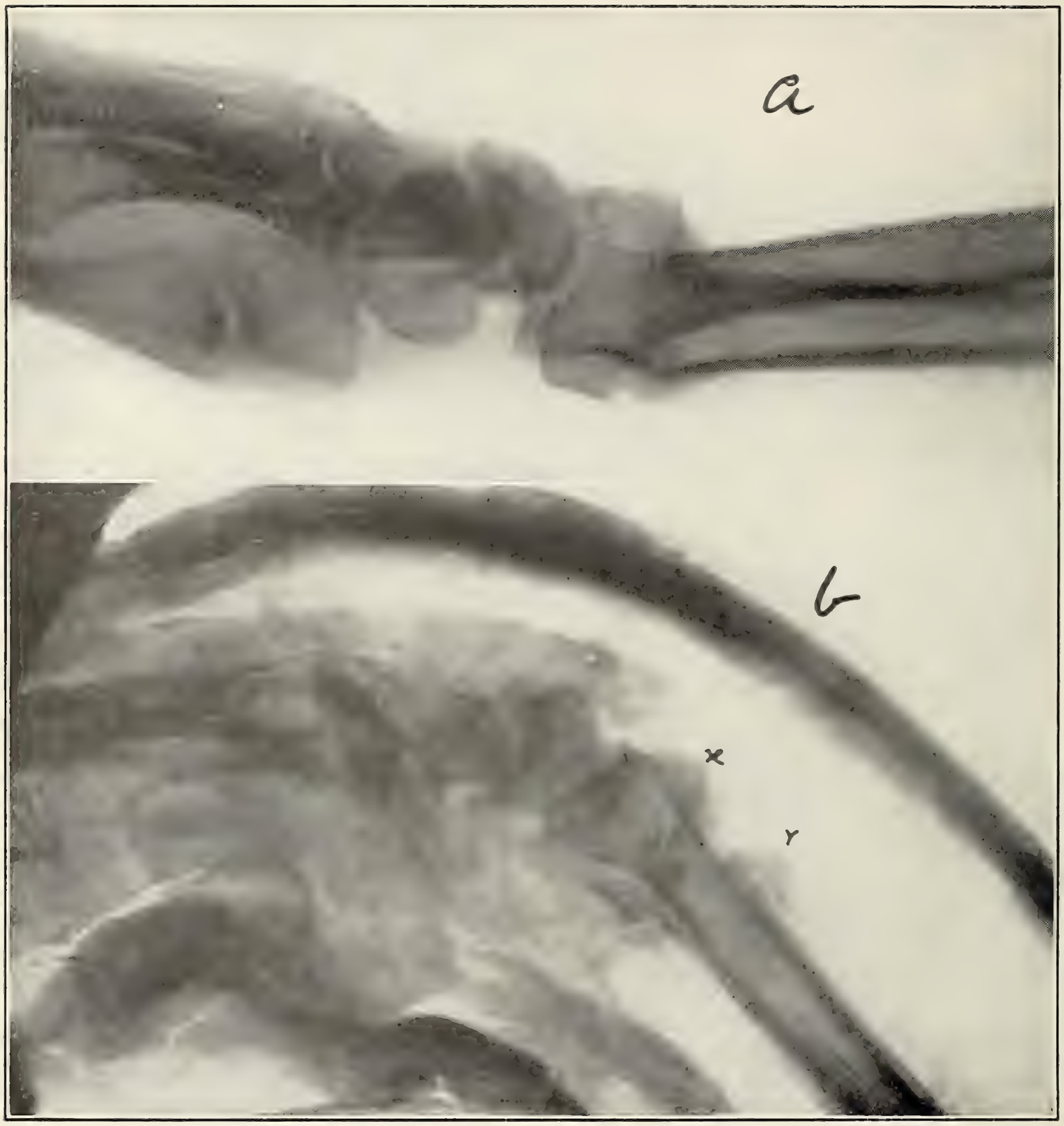

FIG. 401. *a*. COLLES' FRACTURE 10 WEEKS OLD. Extreme displacement of radial fragment. Ulnar head locked in front of carpus. Entire loss of flexion of wrist and of supination. Finger flexion interfered with to unusual degree. *b*. SAME AFTER OPEN REDUCTION—Osteotomy, then reduction by the manipulators described in the text. Shown held in flexion plaster. Note the V-shaped gap between x and y, successfully held open. (*Boston Medical & Surgical Journal.*)

tinued to a total of from three to four weeks. After this a wrist strap only should be used. Motion should always be practiced, and massage employed as needed.

That is all, in the uncomplicated cases, and in our experience no stiffening of hands or ulnar disability is resulting.

If arthritis develops, we must go more slowly all along the line and must expect the usual arthritic course, with recovery greatly postponed.

Late Disabilities. Extensive observation in a large number of cases, hospital, industrial, and private, has indicated to the writer the following facts about late disabilities:

1. Ulnar pain and weakness is the usual complaint. It is never present except when the ulna lies forward, or moves forward on supination.

2. This ulnar looseness is never present unless there is radial deformity, either displacement backward or tipping backward.

3. Recurring dislocation of the ulna with every supination is unexpectedly common. If extensive, it means real disability.

4. If such slipping occurs through a wide range, it determines, not very rarely, a very painful neuritis of the ulnar nerve.

5. Correction of radial contour by operation successfully removes or greatly alleviates all these troubles.[1]

6. Apart from the above, there are no mechanical disabilities that present themselves except that of short radius. Short radius is equivalent to long ulna, and means contact between ulna and carpus.

7. Since the radius can rarely be lengthened, this condition is treated:

a. By osteotomy of the radius and an over-correction, carrying the hand forward and the carpus out of contact with the ulna—a result, in my cases, exactly like the wholly innocent "Madelung's deformity" of developmental origin.

b. By shortening the ulna:

(1) By making a cross-cut and then rabbetting the ends and overlapping them—a pin or plate or suture being set in to hold against the tension of shortened tissues.

(2) By sub-periosteal resection of the lower inch of the ulna. This is a destructive operation, and radical, but it gives a quicker result and is really a bit better than the other method unless the slight deformity resulting is an objection in the given case.

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[1] This had been many times demonstrated before the writer had logic enough to work out the moral of reduction for fresh cases.

Conclusion. In conclusion we may say that Colles' fracture admits of better results than have been usual in the past, and the method of treatment is easy and precise. If proper reduction has not been accomplished, repair of disability or treatment even for appearance is simple, established, and satisfactory. But it is far more important to secure proper reduction in the first place.

BURSÆ

Diagnosis and Treatment of Their Surgical Lesions

By Robert B. Osgood, M.D.

Boston, Mass.

Function. The normal function of a bursa is to facilitate movement between two contiguous structures. These contiguous structures may not be of the same type. Bursæ may be interposed between subcutaneous tissue and a joint capsule, between joint capsule and bone, between bone and overlying soft parts, tendons, and muscles, and between muscle planes. If abnormal conditions are present, abnormal bursæ may develop, and function as do the constant bursæ. Examples of these adventitious bursæ are the common bunions over the great toe joint and the bursæ which often form over the kyphoses in vertebral caries. Wherever found, they facilitate movement and allow structures in close anatomic relation to glide by one another without friction.

Structure. Bursæ are composed of an external layer of connective tissue of varying degrees of thickness, depending upon the function. If the bursa is functioning normally this connective tissue is thin, but if it is subject to irritation or inflammation from trauma or infection, the tissue may become greatly thickened.

The essential tissue in a bursa is its lining membrane. There is lack of agreement among embryologists, histologists, and pathologists as to the remote origin of the cells of the lining membrane of bursæ. The long, flat cells surely resemble endothelial cells, but they are probably not of the same embryonal origin as the endothelial cells of the blood vessels, which seem to develop only by budding, and not from connective tissue cells. In the adventitious bursæ, whose lining membrane seems in all respects similar to the lining membrane of the constant bursæ, we should expect to find no embryonal cells. Moreover, certain bursæ communicate with joints, and the synovial membrane of the joint seems to be continuous with and in every way similar to the lining membrane of the bursæ.

In the light of our present knowledge it is perhaps safest to describe the lining membrane of joints and bursæ as a serous membrane, analogous to the serosa of the pleura, the pericardium, and the peritonium.

Like synovial membrane, it has the power of secreting a light amber fluid, having the properties of synovial fluid. It is subject likewise to the changes which synovial membrane undergoes in response to irritation, from either trauma or infection. Bursitis, like synovitis, may result in a rapid over-secretion of fluid or in a gradual change of structure, proliferative in nature, with the formation of villi or tabs within its walls. Bursal affections, acute and chronic, have been called hygromata or moist tumors. The adhesions or the villous irregularities of the lining membrane which may follow a bursitis may interfere seriously with its normal function, causing pain or sensations of catching. When a bursa is a constituent part of the normal mechanism of a joint, as in the shoulder, elbow, hip, or knee, these changes may seriously limit joint motion in those directions in which the gliding of the bursal walls on one another is a concomitant part of the joint motion. As a less common response to irritation, circumscribed irregular deposits of a material much less radiable than the surrounding soft parts appear in the roentgenogram. They are most commonly recognized in the shoulder region, where they are prone to occur in or about the tendon of the supraspinatus in the floor of the subdeltoid bursa. They are found, however, in other localities (Berry),[14] but are rarely discrete within the bursal sacs. Brickner[13] thinks they are a response to traumatism and occur in necrosed tissue about, but not in, the bursa itself. These calcareous deposits may be present in three forms (Moschcowitz)[12]: (1) as small, sandlike particles within necrosed tissue; (2) as diffuse, massive calcification of the necrosed tissue, and (3) as isolated, discrete, sharply defined nodules. Sometimes the deposit which produces the shadow has been found by Moschcowitz to be in liquid form. This may well explain both their occasional rapid appearance and disappearance and the failure to find at operation the circumscribed bodies which the Rœntgen ray seems to demonstrate. On exploration these are sometimes found free in the bursal cavity, but more commonly are attached to the walls, and often so intimately connected with the wall as to make their removal impossible without dissecting away the wall itself.

Bursæ, therefore, would seem from their structure to be susceptible to nearly all the lesions of synovial membrane, from simple trauma, sudden or repeated, to infections, acute or chronic. We are familiar with acute traumatic or infectious bursitis of the shoulder and knee, and with the chronic bursitis of the elbow and hip, which may be due to overuse or to slowly progressive infection like tuberculosis.

Kanavel[8] has shown how important it is for the surgeon to be familiar with the anatomic distribution and the limits of the bursæ of the hand in order to treat intelligently acute infections of the palm and wrist if future function is to be conserved. Familiarity with the location and extent of the bursæ about the shoulder, elbow, hip, and knee is of almost equal importance in the treatment of the potentially crippling bursal lesions which may occur in these regions.

Neoplasms of bursæ are rare, but cases of fibrous myxoma, chondroma, sarcoma, and endothelioma have been reported (Bolognesi).[9] Syphilitic disease of the bursæ was first described by Verneuil,[10] and, though uncommon, should be considered in indolent lesions of both the adult and child (Coues).[11]

Diagnosis and Treatment of Common Affections of Bursæ.

In the diagnosis of bursal affections the most constant indication is pain, always localized, and sometimes referred as well. The next most constant sign is tenderness to pressure over the bursa. In the acute and many of the chronic conditions, swelling is also present, varying from a marked distention to slight thickening of the walls which may be evident only to careful palpation. A roentgenogram rich in soft part detail will usually reveal this distention or thickening of the walls and disclose the absence or presence of the so-called calcareous deposits.

Limitation of motion in certain appropriate directions in lesions of bursæ about joints will vary from a protective muscular spasm so intense as to interfere seriously with all motion in an acute infection, to no limitation at all on passive motion, or even on active motion if the patient possesses sufficient fortitude to bear the varying amount of pain which such active motion usually produces.

In lesions of deep-seated bursæ, such as those between the tendon of the psoas and the lesser trochanter, or in the popliteal space between the muscular insertions and their underlying structures, one must often depend upon familiarity with the symptoms caused by such affections rather than upon well marked physical signs.

If voluntary motion is limited, the surgeon must carefully determine whether this limitation is due to pain and protective muscular spasm which the patient cannot voluntarily overcome, or whether it is due to an actual tear and separation of a muscle insertion in close relation to the bursa. Perhaps the region where such a lesion most commonly occurs and in which the injury is fraught with most serious consequence, is the shoulder, as Codman[6] has pointed out. The supraspinatus tendon is inserted into the greater tuberosity of the humerus directly beneath the subacromial bursa, and if it is torn from its attachment a traumatic bursitis is almost sure to occur from injury to the bursal floor. In all traumatic affections of the subdeltoid or subacromial bursa, therefore, this lesion should be suspected and the power or lack of power of the patient to initiate abduction should be tested. If this power is persistently absent, partial or complete separation of the insertion of the supraspinatus is likely to have taken place.

Treatment. Acute Traumatic and Toxic Bursitis.

These affections almost constantly subside in from one to two weeks under rest and the many forms of hyperæmic treatment, such as counter-irritation, hot fomentations, baking, etc. The underlying source of the toxæmia must be sought and eliminated, but recovery from the bursitis under local treatment often precedes such elimination. Bursitis is a fairly common accompaniment of lead poisoning.

In these acute cases there is real danger of adhesive changes occurring in the bursa from too prolonged immobilization. The patient should be directed to force the joint gently once or possibly twice a day through all its essential motions by voluntary contraction of his muscles, to the limit of toleration, as soon as the most acute symptoms begin to lessen. If this precaution be carried out there is little danger of firm adhesions forming. If it is not, there is serious danger of a limitation of motion so troublesome as to require forcible manipulation or open operation.

Acute Infections. In the presence of an acute infection there is no standard rule of procedure. We have learned that acute secondary infections of the knee joint, for example, often recover with perfect motion from repeated aspiration, even when the aspirated fluid is purulent and organisms can be grown from cultures. Superficial bursæ may often safely be poulticed or aspirated, therefore, even when purulent contents are suspected; always provided that the condition of the patient is good and whatever constitutional symptoms he may have are in the judgment of the surgeon not caused by the bursal infection. The same indications for surgical drainage obviously obtain in bursæ as in joints, but we have grown to place more reliance on the resistance of the synovial membrane of joints and the secreting membrane of bursæ than we did before the war, and "primum non nocere" is still the rule of conduct. Continued gauze wick drainage tends to cause adhesions in bursæ as in joints, and as in joints also early active motion tends to prevent them and to conserve motion.

Chronic Bursal Affections. Before treatment can be instituted in chronic affections of bursæ, the nature of the affection must be accurately determined. This is by no means always easy. The history of a sufficient acute or of a repeated slight trauma or a quickly subsiding acute toxæmia or infection presupposes that a chronic, non-progressive affection which may follow is due to adhesions or villous formations within the bursa. If such a symptom-complex is presented in practice the surgeon, after having ruled out a tear of a neighboring muscle insertion, is perhaps justified in attempting, with or without an anæsthetic, to put the joint through its normal range of motion, slowly and guardedly, but forcefully, protecting at the same time as far as possible neighboring structures and avoiding any churning or repeated manipulations. The joint should then be temporarily held in a position other than that from which the manipulation released it, and the patient directed to move the joint actively through its various arcs of motion twice daily.

If the symptoms in a chronic affection of the above etiology are those of pain and catching, or if a "jog" occurs at a constant point in an arc of motion, little benefit is likely to be derived from brisement forcé, and fixation should not be carried out for long periods if no relief follows. Exploration of the bursa should be undertaken and the offending tabs removed, or the whole bursa removed with the assurance that nature will construct another if it is needed.

In chronic affections of obscure etiology, forceful passive manipulation, or even voluntary exercises on the part of the patient, are unsafe. Bursæ frequently communicate with joints and are so constantly in close relation to them that morbid processes such as tuberculosis, although originally limited to the bursa, may conceivably be communicated to the neighboring joint by forcible manipulation. It is conservative surgery to explore such chronic bursæ in which the etiology of the lesion is obscure, and if a diseased condition not likely to respond to mechanical or medicinal treatment is encountered, to excise the whole bursa. In our experience tuberculosis is by far the most common chronic affection of bursæ in which the etiology is generally obscure.

Calcareous Deposits in Bursæ. One of the many reasons for insisting, in doubtful or chronic cases of bursal lesion, upon roentgenograms as a routine diagnostic measure is to determine the presence or absence of calcareous deposits. When they are found they usually suggest a process of long standing, likely to be a little recalcitrant to treatment and perhaps more likely to recur after subsidence unless precautions against repeated trauma are taken. Their presence was formerly considered as a justification for operation and removal. It should no longer be so considered as a routine. Unless other reasons as outlined above exist which make exploration of the bursa advisable, calcareous deposits may well be ignored in the treatment. They are frequently present in or about bursæ which function quite normally. They are often found to have disappeared entirely in subsequent roentgenograms, and their removal is often impossible without removal of the bursa itself, which may be unnecessary.

Anatomic Distribution of Bursæ. In describing the various recognized bursæ of the body, the name of the bursa will be given and its anatomic relations. Where a common etiologic factor for a bursitis is known it will be mentioned, as will the characteristic signs and symptoms. The surgical approaches to the subcutaneous bursæ need no comment. A few advantageous approaches to the deep bursæ will be suggested.

It is possible that many small constant bursæ have never been recognized or described. Morbid processes in such obscure bursæ may account for various rather definite clinical pictures which are hard to understand on any other etiologic basis. The bursæ will be described under the main joint regions. The most important and probably the most commonly affected bursæ of the shoulder joint region are the subdeltoid and subacromial bursæ, or the continuous sac composed of the two. Codman's[6] studies of these bursæ are the most complete and should be reviewed. A bursitis of these bursæ is still commonly mistaken for a lesion of the shoulder joint proper or diagnosed as a neuritis.

BURSÆ OF THE SHOULDER JOINT

1. Subdeltoid bursa (Bursa subdeltoidea).

Relations. Lying between the under surface of the deltoid muscle and the outer surface of the capsule, this bursa does not communicate with the joint, but often communicates with the bursa next to be described, the Subacromial Bursa, with which it is frequently continuous, so that the names subdeltoid and subacromial are frequently employed synonomously.

The subacromial bursa (Bursa subacromialis) proper lies between the under surface of the acromion and the coraco acromial ligament above, and the capsule and insertion of the supraspinatus muscle below. The supraspinatus insertion forms a part of its floor.

These bursæ are irregular but roughly oval in outline. They are fairly large, but vary in size.

Etiology. Their affections are usually due to direct or indirect trauma, toxins, or infections.

Symptoms. Calcareous deposits are prone to occur in the walls. Affections of these bursæ are the common causes of "stiff shoulders" and painful shoulders, and are often diagnosed as "neuritis." The motions of the shoulder joint which are most limited by them are those of abduction and rotation, especially rotation in abduction. The forward and backward motions of the shoulder are usually free.

Surgical Approach. The bursæ may be opened by a linear incision separating the fibres of the deltoid. This approach is satisfactory for drainage, but not for careful exploration, clean dissection of adhesions, or repair of a torn supraspinatus tendon. The tendon lies too deep beneath the acromion process in the floor of the subacromial bursa. The most practical and harmless approach is by the sabre shaped incision of Codman,[20] as described by Binnie. It begins over the spine of the scapula and runs forward, dividing the acromioclavicular joint, continuing anteriorly between the fibres of the deltoid. The acromion process is divided at its base with an osteotome or saw, and turned downward and forward with the portion of the deltoid arising from it. The bursæ are thus fully exposed. Unless the transparent walls of the bursa are thickened, the capsule of the shoulder joint seems to present, but careful dissection, even in a normal subject, will reveal a constant bursa of large extent.

In closing, the deltoid and acromion are folded back. The acromion does not tend to displace itself, but may be fastened to its divided base by a kangaroo stitch. The capsule of the acromioclavicular joint is sutured. The separated muscle fibres usually require no suture. The arm is retained in abduction and usually outward rotation.

2. Posterior subscapularis bursa (Bursa m. subscapularis posterior).

Relations. This bursa lies between the upper part of the deep surface of the subscapularis and the neck of the scapula, the coracoid process, and the capsule of the shoulder joint. It communicates with the joint by an opening below the coracohumeral ligament (ligamentum coraco humerale) and represents really a bulging of the articular capsule, oval in shape.

Etiology. Its affections are usually those of the shoulder joint, of which it is an extension.

Surgical Approach. The tendon of the subscapularis muscle must be divided, after drawing to one side the origin of the coracobrachialis.

3. Anterior subscapularis bursæ (Bursæ m. subscapularis anterior).

Testut, 1911 edition, p. 520,[2] describes a small bursa between the anterior surface of the tendon of the subscapularis muscle and the coracobrachialis muscle, and another between the anterior surface of the tendon of the subscapularis muscle and the short head of the biceps.

Etiology. Their affections are not generally recognized, if any exist.

Surgical Approach. As they lie beneath the coracobrachialis muscle and the short head of the biceps, these structures must be divided or displaced laterally.

4. Coracobrachialis bursa. (Bursa m. coracobrachialis.) A well defined almost constant bursa, oval in shape, is found between the tendon of the subscapularis muscle and the coracoid process and insertion of the coracobrachialis muscle.

Etiology. Its affections are usually due to trauma, direct or indirect to toxins, or to infections.

Symptoms. Calcareous deposits are not common, and the symptoms and signs may well be mistaken for those of a subacromial or subdeltoid bursitis. The tenderness is more sharply localized and more anterior, directly beneath the coracoid process. Backward movement of the shoulder may be limited.

Surgical Approach. Operative procedures are rarely necessary. To approach the bursa satisfactorily, the origin of the coracobrachialis must be separated from the coracoid process.

5. Coraco-Clavicular bursa. (Bursa ligamenti coracoclavicularis.) A small bursa exists fairly constantly between the conoid and trapezoid portions of the coraco-clavicular ligament.

6. Infra spinatus bursa. (Bursa m. infraspinati.) A small bursa is often found between the tendon of the infra spinatus muscle near its insertion and the capsule of the shoulder joint.

7. Bursæ of the latissimus dorsi. (Bursæ m. latissimi dorsi.) Two bursæ are described (Spalteholz, 2nd American Edition, p. 300[3] and Testut, 1911 Edition, p. 520[2]), one on the anterior surface of the tendinous insertion of the latissimus dorsi, between it and the overlying tendinous insertion of the pectoralis major, and the other beneath the tendinous insertion of the latissimus dorsi and the humerus and underlying tendinous insertion of the teres major muscle.

8. Bursæ of the teres major. (Bursæ m. teretis majoris.)

Two bursæ are described (Spalteholz, 2nd American edition, p. 300, and Testut, 1911 edition, p. 520), one between the tendon of insertion of the teres major and the humerus, and the other between the posterior surface of the teres major muscle on its way to the scapula and the anterior surface of the long head of the triceps muscle as it passes beneath the teres major muscle and at right angles to it.

Subcutaneous Bursa.

9. Acromial bursa. (Bursa subcutanea acromialis.) Quite frequently a bursa of varying size is placed beneath the subcutaneous tissue and the upper surface of the acromion process.

BURSÆ IN THE REGION OF THE ELBOW JOINT

The most common bursal lesion of the elbow is the so-called miner's elbow, in which the subcutaneous bursa over the olecranon process is involved.

Perhaps the next most common bursal affection is the so-called tennis elbow or epicondylitis in the region of the lateral (external) condyle, which Toldt (English edition, p. 321[4]) ascribes to an irritation of the bicipitoradiale or the interosseous bursa near the tubercle of the radius. Osgood (Archives of Surgery, May 1922[7]) considers the typical tennis elbow to be caused by the irritation of an hitherto undescribed but fairly constant bursa, which he calls the radiohumeral bursa, between the conjoined extensor tendon, the tip of the condyle, and the supinator brevis muscle which originates from the lateral condyle and the capsule of the radio-humeral joint. The location of the bursa is over the radiohumeral joint. The point of usual tenderness and swelling is found well above the bicipito-radial and interosseous bursæ, nearer the epicondyle—hence the old name epicondylitis.

1. Olecranon bursa (Bursa subcutanea olecrani). A superficial subcutaneous sac of varying size, situated beneath the skin, between it and the tendinous expansion of the triceps muscle, where this is inserted into the olecranon process.

Etiology. The common etiology of lesions of this bursa is trauma, usually repeated and occupational, but sometimes sudden, as from falls.

Symptoms. Swelling and often superficial redness, heat, and tenderness are the symptoms. In the chronic affection known as miner's elbow this sac sometimes attains a large size, with thick walls, and contains villi.

2. Radiohumeral or supinator brevis bursa. (Bursa radio humerlae). A small, fairly constant bursa between the common tendon of the extensors and the supinator brevis muscle, over the radiohumeral joint.

Etiology. Any sport or occupation, tennis, boxing, plastering or painting, which induces a sudden cessation of incomplete extension with the hand pronated, may irritate the bursa. It may be involved in lead poisoning.

Symptoms. Tenderness sharply localized, seemingly over the lateral (external) condyle. If the tissues are pulled away from the condyle, pressure on the condyle itself will be found to be painless and the true tenderness will be found a little distal and medial, nearly over the radiohumeral joint. A sense of weakness in the arm and radiating pain are often complained of, presumably from pressure on the posterior interosseous nerve between the two planes of the supinator brevis muscle. Pain is experienced in carrying a weight with the arms extended, such as a bag, or in gripping when the extensors are set.

In lead poisoning the bursa is frequently affected in both right and left arms. The symptoms from affections of this bursa are prone to be chronic and annoying, interfering with sport and occupation. They are also very difficult to relieve by partial fixation and physiotherapeutic measures. Many mild cases are relieved by a plaster strapping, applied with the elbow flexed and the hand supinated, starting from the anterior mid-surface of the forearm and continuing upward and backward over and around the lateral (external) condyle and radiohumeral joint, limiting pronation and full extension of the elbow. This strapping is renewed weekly for from four to six weeks. Mild cases are also satisfactorily relieved by fixation in a right angle plaster cast for six weeks, followed by gradual use and physiotherapy, but they may recur on a repetition of the original traumatic cause. They have been permanently relieved by opening the bursa and curetting its walls.

Surgical Approach. With the hand in supination, an oblique linear incision is made of 4—5 om. (2 inches) from just above the lateral (external) condyle distalwards in line with the styloid process of the radius, and carried through the common extensor tendon. It requires careful dissection to find an uninflamed or quiescent bursa, but a distended one is met as soon as the common extensor tendon is split. It may be that a bursa exists between the two planes of the supinator brevis muscle, but in dissections and at operation it seems superficial to the origin of the supinator brevis, and its extension over the tip of the lateral (external) condyle would also support this location. In opening the bursa, care must be taken not to injure the posterior interosseous nerve lying between the two planes of the supinator brevis muscle.

3. Bicipito-radial bursa (Bursa bicipito radialis). Between the tendon of insertion of the biceps and the tubercle of the radius.

4. Interosseous bursa (Bursa cubitalis interossea). This bursa is in relation laterally with the tendon of the biceps, and medially with the ulna and the oblique ligament (chorda obliqua) of the interosseous membrane, and it tunnels behind the supinator brevis muscle. (Spalteholz, 2nd American Edition, p. 303. Toldt, English Edition, 1904, Third Section, p. 321.) The bursa lies in the bicipital hollow of the ulna. In pronation the tubercle of the radius lies in this hollow, the bursa forming a synovial cavity between these two bones. The tendon of insertion of the biceps thus lies between the bicipito-radial bursa (See 3 above) and the interosseous bursa.

Etiology. These bursæ are prone to irritation in sport, especially in baseball pitchers.

Symptoms. Pain and weakness on sudden contraction of the biceps accompanied by pronation are the symptoms.

5. Subtendinous bursa of the triceps (Bursa subtendinea olecrani). Between the tendon of the triceps and the olecranon process. It is not constant.

6. Intratendinous bursa of triceps (Bursa intratendinea olecrani). Between the fibres of the tendon of insertion of the triceps proximal to the subtendinous bursa of the triceps. (See 5 above.) This is a fairly constant bursa.

7. Subcutaneous condylar bursæ (Bursæ subcutaneæ epicondyli humeri lateralis et epicondyli humeri medialis). Between the skin and the condyles of the humerus. These bursæ are seemingly adventitious, and are found inconstantly in adult life. The medial (internal) is said to be the more constant, but in our experience the lateral (external) has been more frequently recognized and calcareous deposits have been found within it in several reported cases.

BURSÆ IN THE REGION OF THE WRIST AND HAND

The most important bursal formations of the wrist and hand are the synovial sheaths of the tendons of the palm and the dorsum.

Kanavel's careful studies (Infections of the Hand, 3rd edition, Philadelphia, 1916[8]) have demonstrated the importance of knowing the usual arrangement and common variations of these bursæ in combatting the common hand infections which are potentially so crippling. They are often the seat of tuberculous and other chronic infections, and frequently contain masses of small yellowish fibrous bodies called rice bodies.

The other deep and subcutaneous bursæ are of minor importance surgically and are rarely subject to recognized affections.

1. In the palm is situated the large serous bursa of the flexor profundus and the flexor sublimis muscles, called the **ulnar bursa** (Vagina tendinum m. m. flexorum communium), extending proximally beneath and a short distance above the annular ligament, and distally into the palm, usually continued along the tendon of the flexor of the little finger. The ulnar side of the bursa is free, while the radial side envelops the tendons, as Kanaval says, "as if they were pushed in along the outside." It does not as a rule communicate with the distal vaginal sheaths which invest the flexor tendons of the index, middle, and ring fingers (Vaginæ tendinum digitalis). It sometimes communicates with the serous bursa of the flexor longus pollicis, called the **radial bursa** (Vagina m. flexoris pollicis longi), lying close to it. This serous bursa also extends proximally beneath the annular ligament and continues distally along the tendon into the thumb.

Frequently (Testut, Traité d'Anatomie Humaine, Edit., 1911) there is a third, and sometimes a fourth, separate serous bursa investing the flexor tendons of the index finger, extending on both sides of the annular ligament, but still not communicating with the vaginal sheath of the finger. These are called by Kanavel the **intermediary, anterior, and posterior palmar synovial sheaths.** He says that the intermediary posteriar palmar sheath should be described as a normal sheath, since it is present in about 80 per cent of the subjects examined. "It lies between the carpal canal and the flexor profundus of the index finger, and commences above the wrist at the edge of the radius. It spreads out at the level of the upper border of the semilunar bone and goes down more or less on the tendon of the flexor profundus." "It is by the intervention of this sheath that the ulnar and radial bursæ ordinarily communicate." The anterior intermediary palmar sheath is found in hardly 50 per cent of the subjects examined. When present it is smaller than the posterior intermediary sheath and is situated between the superficial and deep tendons of the index finger.

The important structures in relation to the ulnar and radial bursæ are the median nerve, lying deeply between them, the middle palmar space, lying beneath the ulnar bursa, and the superficial palmar arch, lying above it.

2. On the dorsal surface there is also a large **dorsal central serous bursa** surrounding the tendons of the extensor communis digitorum and extensor indicis (Vagina tendinum m. m. extensoris digitorum communis et extensoris indicis). The sac extends beneath the dorsal ligament and a short distance beyond it on the dorsal surface distalwards.

Vaginal sheaths invest the tendon of the extensor longus pollicis (**Vagina tendinis m. extensoris pollicis longi**); the tendon of the extensor brevis and the extensor ossis metacarpi pollicis or abductor longus pollicis (**Vagina tendinum m. m. abductoris longi et extensoris brevis pollicis**); the tendon of the extensor carpi radialis longi and brevior (**Vagina tendinum m. m. extensorum carpi radialium**); the tendon of the extensor minimi digiti (**Vagina tendinis m. extensoris digiti V**); and the tendon of the extensor carpi ulnaris (**Vagina tendinis m. extensoris carpi ulnaris**).

There are no vaginal investments of the extensor tendons of the fingers.

3. **Extensor carpi radialis brevis bursa (Bursa m. extensoris carpi radialis brevis).** Fairly constant between the tendon of insertion of the extensor carpi radialis brevior and the base of the third metacarpal bone.

4. **Extensor carpi radialis longus bursa (Bursa m. extensoris carpi radialis longus).** A less constant small bursa is sometimes placed between the tendon of insertion and the extensor carpi radialis longus and the base of the second metacarpal. (Gray, American Edition, Philadelphia: 1913, p. 487[5]).

5. **Flexor carpi ulnaris bursa (Bursa m. flexoris carpi ulnaris).** Frequently present between the tendon of insertion of the flexor carpi ulnaris and the pisiform bone.

6. **Inter-metacarpo-phalangeal bursæ (Bursæ inter-metacarpo-phalangeæ).** These small bursæ are frequently found between two adjacent fingers toward the dorsal surface interposed between the heads of the metacarpal bones.

7. **Subcutaneous dorsal finger bursæ (Bursæ subcutaneæ metacarpo-phalangeæ dorsalis et bursæ subcutaneæ digitorum dorsales).** These small bursæ just beneath the skin are quite constant (Spalteholz, 2nd American Edition, p. 324), over the metacarpophalangeal joints, over the small joints of the fingers, and occasionally over the second joints of the second and fourth fingers.

BURSÆ IN THE REGION OF THE HIP JOINT

The two bursæ in the region of the hip joint in which affections are most commonly recognized, because they are most crippling, are the gluteal bursa (Bursa trochanterica m. glutæi maximi) and the iliopectineal bursa (Bursa ilio pectinea). Chronic diseases like tuberculosis are not uncommonly found affecting these bursæ, the latter of which, the iliopectineal, frequently communicates with the hip joint, and the former, the gluteal, involves the hip joint, if the disease which primarily invades it is not eradicated.

In gluteal bursitis, the motions of flexion and inward rotation are limited, and in iliopectineal bursitis hyperextension of the thigh and inward rotation are limited.

A third and very frequent bursa is the ischial bursa (Bursa ischiadica m. glutæi maximi). Affections of this bursa are usually traumatic or occupational, as is evidenced by the rather graphic name of weaver's bottom, by which it is commonly known.

1. Gluteal bursa (Bursa trochanterica m. glutæi maximi).

Relations. The bursa lies between the greater trochanter and the origin of the vastus externus and the gluteus maximus nearer the superior than the inferior portion of its insertion. This is a constant large bursa, usually unilocular, but sometimes made up of several small discrete sacs (Toldt, English Edition, 1904, p. 340).

Etiology. Affections of this bursa are usually due to direct trauma, toxins, or infections. Tuberculous disease has frequently been found confined to this bursa, but is usually mistaken for hip disease.

Symptoms. Pain on motion of the hip, especially flexion and inward rotation, is present, as is also generally tenderness to pressure over its area, and in marked affections a swelling recognizable on inspection and felt on palpation when compared with the unaffected side.

Surgical Approach. The bursa may be opened by an incision through and in line with the fibres of the gluteus maximus at about the level of the junction between the middle and upper thirds of its insertion.

2. Femoral bursæ (Bursæ glutæi femorales). Two small bursæ, fairly constant, are found between the lower portion of the tendon of insertion of the gluteus maximus and the femur and the upper part of the vastus externus.

3. Iliopectineal bursa (Bursa ilio pectinea). Often called the ilio psoas bursa.

Relations. This constant, important, large bursa is placed between the ilio psoas muscle and the ilio femoral capsular ligament (the Y ligament of Bigelow). It frequently communicates with the hip joint proper—in Lund's[15] examinations three times out of eighteen. It is variable in size and may extend above the pelvic brim.

Etiology. The bursa is sometimes involved in disease of the hip joint, but is rarely subject to traumatic affections, except sudden strains of the psoas muscle. Acute suppurative processes and Neisserian infections have been encountered, and in all of Lund's[15] three cases there was associated the disease of the hip joint. Cullen[18] has reported a large cystic tumor developing from this bursa, containing free cartilaginous masses, and communicating with the hip joint.

Symptoms. Pain and a palpable swelling over the anterior portion of the hip joint capsule are present. Hyperextension and sometimes inward rotation of the thigh should be limited. The thigh is often held in slight flexion. One may easily mistake a swelling in this bursa for a psoas abscess or even an old hernial sac. The bursa lies almost directly beneath or slightly medial to the anterior crural nerve, and should be approached by a vertical incision starting near the anterior superior spine and continuing along the medial (internal) border of the tensor fasciæ femoris muscle. This muscle should be retracted laterally (outward) and the sartorius and rectus muscles, with the nerves and vessels, medially (inwards).

4. **Pectineal bursa (Bursa m. pectinei).** This small bursa is placed between the tendon of insertion of the pectineus and the tendon of the iliopsoas, and sometimes between the tendon of insertion of the pectineus and the femur (Toldt, Atlas of Human Anatomy, English Edition, 1904, p. 347).

5. **Subtendinous ilio psoas bursa (Bursa iliaca subtendinea).** A small bursa is frequently found between the tendon of insertion of the ilio psoas and the lesser trochanter of the femur.

6. **Quadratus femoris bursa (Bursa m. quadratus femoris).** A bursa is often found between the deep surface of this muscle and the lesser trochanter which it covers on its course to its insertion (Gray, American Edition, Philadelphia, 1913, p. 521).

7. **Rectus bursæ (Bursæ m. recti femoris).** Fairly constant small bursæ are found (1) between the tendon of origin (reflected head) of the rectus and the lip of the acetabulum, and (2) between the tendon of origin and the anterior inferior spine of the ilium (Toldt, Atlas of Human Anatomy, English Edition, 1904, p. 348).

8. **Gluteus medius bursæ, anterior and posterior (Bursæ trochantericæ m. glutæi medii anterior et posterior).** (1) The

anterior bursa is constant and is situated between the tendon of insertion of the gluteus medius and the apex of the great trochanter. (2) **A posterior bursa** is freqently present between the tendon of insertion of the gluteus medius and the tendon of the pyriformis muscle.

9. Gluteus minimus bursa (Bursa m. glutæi minimi). A fairly constant small bursa exists between the tendon of insertion of the gluteus minimus and the greater trochanter.

10. Ischial bursa (Bursa ischiadica m. glutæi maximi). This frequently present bursa, the occupational irritation of which is known as "weaver's bottom," is situated between the posterior surface of the tuberosity of the ischium and the tendons of origin of the biceps, semitendinosus muscles, and the deep surface of the gluteus maximus muscle. Persons much in the saddle are prone to irritation of these bursæ (Friend[19]).

11. Superior bicipital bursa (Bursa m. bicipitalis femoris superior). An inconstant bursa is sometimes found between the tendons of origin of the biceps and the semitendinosus on the one hand and the tendon of origin of the semimembranosus on the other.

12. Pyriformis bursa (Bursa m. pyriformis). This is a frequently found bursa lying in front of and below the tendon of insertion of the pyriformis, between this tendon, the superior gemellus muscle, and the ilium.

13. Obturator internus bursa (Bursa m. obturatoris interni). A constant bursa is situated between the lesser sciatic notch and the tendon of insertion of the obturator internus. This serous cavity frequently extends into the groove in the ischial tuberosity, which contains the two gemelli muscles and for which it forms the lining. It occasionally communicates with a commonly existent serous sac placed between the tendon of the obturator internus muscle and the capsule of the hip joint (Spalteholz, Second American Edition, p. 343).

Subcutaneous Bursæ in the Pelvic and Hip joint Region

14. Subcutaneous trochanteric bursa (Bursa trochanterica subcutanea). This fairly constant bursa is situated between the subcutaneous tissue and the prominence of the greater trochanter.

15. Numerous small unimportant subcutaneous bursæ are found, the most constant of which are (1) the bursa between the posterior superior spine and the subcutaneous tissue **(Bursa subcutanea spinæ iliacæ posterioris)**; (2) the bursa between the sacrum and the subcutaneous tissue **(Bursa subcutanea sacralis)**; and (3) the bursa between the coccyx and the subcutaneous tissue **(Bursa subcutanea coccygea).**

BURSÆ IN THE REGION OF THE KNEE JOINT

In the region of the knee joint the bursæ which are most commonly affected are those associated with the extension mechanism of the quadriceps and the flexion mechanism of the hamstrings.

A prepatellar bursitis is known as "Housemaid's knee," and is caused most commonly by continual trauma, though this subcutaneous bursa is subject also to infections.

The infrapatellar bursa is subject to both traumatic and infectious affections. Neither of these bursæ communicates with the main synovial cavity of the knee joint, though their involvement is often confused with involvement of the knee joint proper. A bursitis of either of these bursæ makes flexion painful and limited. The bursæ at the back of the joint most commonly irritated are the bursa of the semimembranosus muscle and the bursæ of the gastrocnemius, the affections of which are infrequently due to direct trauma, but the involvement of which often limits extension. All of these posterior bursæ frequently communicate with the synovial cavity of the knee joint.

The bursa beneath the popliteus muscle is really only a prolongation of the synovial cavity of the knee joint, and subject to all the affections of the true joint.

1. Prepatellar bursa (Bursa præpatellaris subcutanea).

Relations. This is commonly a single large bursa between the subcutaneous tissue and the anterior surface of the fascia lata. There may be two other bursæ between deeper planes of tissue, or the main bursa may be placed between either of these deeper planes. Thus we may find a bursa prepatellaris subfascialis, posterior to the fascia lata, between it and the tendinous expansion of the quadriceps, or a bursa prepatellaris subtendinæ, between the expansion of the quadriceps and the anterior surface of the patella.

Etiology. Irritation of this bursa or bursæ is commonly caused by kneeling occupations—hence the name "Housemaid's knee"—but tuberculosis and other infections have been recognized in the bursa.

Symptoms. Pain, tenderness, swelling, and often heat and redness are present. Flexion of the knee joint is limited to a variable extent, depending upon the swelling or the acuteness of the inflammation.

The **surgical approach** is obvious.

2. Infrapatellar subcutaneous bursa (Bursa infrapatellaris subcutanea) and the subcutaneous bursa over the tibial tuberosity

(Bursa subcutanea tuberositas tibiæ) are two small bursæ which are commonly present, but rarely give rise to symptoms.

3. **Infrapatellar bursa (Bursa infrapatellaris profunda).** This constant small bursa is placed between the posterior surface of the patellar ligament and the anterior surface of the tibia. Masses of fat wall it off from the main joint cavity, with which it rarely connects. It is often irritated in adolescent lesions of the tibial tubercle (Osgood-Schlatter's disease).

The surgeon may approach it either in the median line by a vertical incision through the patellar tendon or laterally through the medial or lateral expansion of the quadriceps insertions. Isolated tuberculosis of this bursa has been recorded (Jones and Lovett, Orthopedic Surgery, page 52).

4. **Suprapatellar bursa (Bursa suprapatellaris).** This is usually indirect communication with the proximal end of the suprapatellar pouch of the knee joint, between the quadriceps tendon and the anterior surface of the femur.

5. **Sartorius bursa (Bursa m. sartorii propria).** (Toldt calls this bursa the bursa anserina, which will be next described, and with which it frequently communicates.) This bursa is found between the aponeurotic expansion of the tendon of insertion of the sartorius and the insertion of the gracilis and semitendinosus muscles on the medial (internal) aspect of the upper portion of the tibia. It is sometimes prolonged between the tendons of insertion of these muscles to the medial (internal lateral) ligament of the knee joint.

6. **Bursa anserina.** This is a constant, fairly large bursa between the tendons of insertion of the gracilis and semitendinosus muscles and the tibia. It frequently communicates with the sartorius bursa.

7. **Semimembranosus bursæ (Bursæ m. semimembranosus).** These two bursæ are constant. One is placed between the tendon of insertion of the semimembranosus and the medial (internal) head of the gastrocnemius muscle in front. It touches also the posterior capsule of the knee joint, with which it often communicates. The other bursa of the semimembranosus is placed between the expansion of the tendon of insertion of the semimembranosus and the medial condyle of the tibia.

8. **Gastrocnemius bursæ. (a) Bursæ m. gastrocnemii lateralis; (b) Bursa m. gastrocnemii medialis).** (a) The lateral or external gastrocnemius bursa is placed between the lateral (external) tendon of origin of the gastrocnemius and the lateral condyle of the femur and the superior portion of the posterior capsule of the knee joint. It not infrequently contains a small sesamoid, and may communicate with the

knee joint cavity. (b) The medial or internal gastrocnemius bursa is placed between the medial (internal) tendon of origin of the gastrocnemius and the medial (internal) condyle of the femur and the superior portion of the posterior capsule of the knee joint. The small upper portion of the bursa may be separate, but it usually is prolonged between the tendons of origin of the semimembranosus and the medial head of the gastrocnemius, and frequently communicates with the knee joint.

9. **Bicipital gastrocnemial bursa (Bursa bicipitis gastrocnemialis).** This is an important bursa, occasionally found between the tendon of insertion of the biceps and the lateral head of the gastrocnemius and plantaris muscles.

10. **Superior and inferior biceps bursæ (Bursæ m. bicipitis femoris superior et inferior).** (a) The superior is inconstant and placed between the tendons of insertion of the biceps and semitendinosus on the one side and the tendon of insertion of the semimembranosus on the other. (b) The inferior is almost constant, and is situated between the tendon of insertion of the biceps and the lateral, or external lateral, ligament of the knee joint over the head of the fibula.

Subject as it is to trauma, this bursa is clinically found often swollen and sometimes inflamed. It may communicate with the knee joint proper. Its walls are often so tense as to suggest an enlargement of the head of the fibula. The close relation of the external popliteal or peroneal nerve to the tendon of the biceps and the head of the fibula must be borne in mind in operations upon this bursa.

11. **Popliteal bursa (Bursa m. poplitei).** This so-called bursa is really a tubelike pocket of the synovial membrane of the knee joint proper, extending distalwards and posteriorly on the lateral or external side of the joint, anterior to and beneath the tendon of origin of the popliteus muscle. Its communications with the joint are usually two: (1) By a narrow slit above the lateral (external) meniscus between it and the tendon of the popliteus muscle, and (2) by an opening below the meniscus. This bursal sac occasionally communicates with the tibiofibular joint.

12. **Rider's bursa.** This is an adventitious subcutaneous bursa, frequently found in riders, between the subcutaneous tissue and the medial (internal) condyle of the femur, caused by pressure and friction between the medial (internal) surface of the knee joint and the saddle.

BURSÆ IN THE REGION OF THE ANKLE JOINT AND FOOT

Perhaps in no other region of the body in civilized peoples are bursal affections more common than about the ankle and foot. In no other region, also, are adventitious bursæ so frequently found. The explanation of these facts is found in the universal custom of wearing shoes, and often of ill-fitting shoes, planned to conform to the prevailing fashion rather than to the natural foot.

The bursal sheaths of the tendons are subject to irritation from the same cause, though less exposed to traumatic infections than the bursal sheaths of the hand. They seem also to be less frequently subject to tuberculous infection. They are by no means immune to infections, however, especially to hæmatogenous infections, as is shown by the frequency of Neisser infections of these bursæ and bursal sheaths. The affections of these bursæ, except an acute sepsis, usually yield to protective and physiotherapeutic measures. When operative procedures are necessary, the surgical approaches are with one or two exceptions obvious, since the bursæ are so superficially placed.

Synovial Bursal Sheaths

1. Synovial sheath of the tendons of the peronæus longus and brevis muscles (**Vagina tendinum m. m. peronæorum communis**). Proximally the bursal sheaths of the tendons of these two muscles are separate. They begin well above the lateral (external) annular ligament of the ankle, pass beneath it, becoming confluent, and emerging, pass again beneath the inferior retinaculum of the tendons, and again investing the individual tendons, are separated from one another by the peroneal spine of the os calcis.

Very rarely the sheath of the peronæus longus may be continued into the sole, but usually there is a space between the ankle bursal sheath and the bursal sheath of the peronæus longus tendon in the sole (**Vagina tendinis m. peronæi longi plantaris**).

2. Synovial sheath of the tendon of the tibialis anticus muscle (**Vagina tendinis m. tibialis anterioris**). This bursal sheath extends from beneath or from the inferior border of the superior annular ligament of the ankle joint to the astragolscaphoid joint, passing beneath the anterior annular ligament.

3. Synovial sheath of the tendon of the extensor longus (or proprius) hallucis muscle (**Vagina tendinis m. extensoris hallucis longi**).

This bursal sheath extends from just proximal to the anterior annular ligament, beneath it and on to the shaft of the first metatarsal bone. It is the most deeply placed of the anterior synovial sheaths.

4. Synovial sheath of the tendon of the extensor longus digitorum and peronæus brevis muscles (**Vagina tendinum m. extensoris digitorum pedis longi**). This bursal sheath extends from midway between the superior and anterior annular ligaments of the ankle joint, beneath the latter, above the third cuneiform bone, nearly to the bases of the second and third metacarpal bones.

5. Synovial sheaths of the tendon of the tibialis posticus muscle (**Vagina tendinis m. tibialis posterioris**). This bursal sheath extends from the level of the medial (internal) malleolus to the region of the scaphoid bone.

6. Synovial sheath of the tendon of the flexor longus digitorum muscle (**Vagina tendinis m. flexoris digitorum longi**). This bursal sheath begins at a slightly more distal level than the sheath of the tibialis posticus tendon and terminates where the tendon of the flexor longus digitorum muscle crosses the tendon of the flexor longus hallucis muscle, somewhat more distally than the sheath of the tibialis posticus muscle. This sheath may communicate with the contiguous sheaths of the tendons of the tibialis posticus and flexor longus hallucis muscles.

7. Synovial sheath of the tendon of the flexor longus hallucis muscle (**Vagina tendinis m. flexoris hallucis longi**). This bursal sheath begins at a slightly more distal level than the sheath of the flexor longus digitorum tendon, and terminates at a point distal to the intersection of the tendon of this muscle.

8. Vaginal sheaths also invest the flexor tendons of the toes from just proximal to the heads of the metatarsal bones to the terminal phalanges. The sheath of the flexor tendon of the first or great toe extends proximalward to nearly the base of the first metatarsal bone. These digital sheaths do not connect with the tarsal sheaths above described.

Bursæ of the Foot

1. Achilles bursa (Bursa tendinis (calcanei Achillis). This is a constant bursa frequently irritated by the stiff counters of new shoes, situated between the most distal portion of the tendo Achillis and the posterior tubercle of the os calcis.

2. Subcutaneous heel bursa (Bursa subcutanea tendinis calcanei (Achillis). In this region there may be one circumscribed, fairly large bursa, or several small bursæ beneath the subcutaneous tissue and over the distal portion of the tendo Achillis.

3. Tibialis anticus bursa (Bursa subtendinea m. tibialis anterioris). This small bursa is placed between the tendon of insertion of the tibialis anticus muscle and the surface of the first cuneiform bone.

4. Tibialis posticus bursa (Bursa subtendinea m. tibialis posterioris). This small bursa is placed between the lateral tendinous expansion of the tibialis posticus muscle and the surfaces of the scaphoid and second cuneiform bones.

5. Tarsal sinus bursa (Bursa sinus tarsi). In the masses of fat which fill up the tarsal sinus between the os calcis and astragalus on the lateral (external) aspect of the foot there is frequently found a bursa near the astragalocalcaneal ligaments.

6. Lumbrical bursa (Bursæ m. m. lumbricalium pedis)· Small bursæ are situated between the tendons of insertion of the lumbrical muscles and the bases of the phalanges.

7. Metatrasophalangeal bursæ (Bursæ intermetatarsophalangeæ). Almost constant bursæ are found between the heads of the first three (medial) metatarsal heads, and occasionally one is present between the heads of the fourth and fifth metatarsal bones.

8. Subcutaneous bursæ (a) Bursa subcutanea malleoli medialis; (b) Bursa subcutanea malleoli lateralis; (c) Bursa subcutanea malleoli calcanea.

These frequently-found bursæ are situated, as their designations would imply, respectively beneath the subcutaneous tissue and the bone of the medial internal malleolus, the lateral (external) malleolus, and the posterior tubercle of the os calcis.

9. Adventitious bursæ of the foot. These bursæ are very common in shoe-wearing people and may develop between the subcutaneous tissue and any bony prominence which is subjected to pressure or frictional irritation. A bursa of considerable size with thickened walls is very common over the great toe joint, and when swollen or inflamed is known as a bunion. It is an almost constant accompaniment of the enlargement of the great toe joint and lateral (outward) deviation of the great toe, called hallux valgus.

Bursal formations are also very common over the head of the fifth metatarsal, the base of the fifth metatarsal, the scaphoid tubercle, and over the joint between the first metatarsal bone and the first (internal) cuneiform, and when short shoes are worn, over the joints on the dorsal surface of the toes.

Bursæ are prone also to occur beneath the inferior tubercle of the os calcis and the plantar fascia, especially if, as is common following Neisserian infections and in later life, a spur has formed on the tubercle. As a rule these bursal irritations are amenable to protective treatment and do not necessitate the removal of the supposedly offending spur.

If irritation occurs on slight provocation, the bursa and spur are most easily approached by a circular incision about the heel and a turning forward of all subcutaneous tissue and plantar fascia. Unfortunately, the disturbance of the circulation by this approach is sometimes so great that sloughing takes place and leaves an easily irritated scar. We believe the lateral approach is safer, although the exposure is not nearly so complete.

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INGROWN TOENAIL

BY

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INGROWN TOENAIL

Table of Contents

Ingrown Toenail 1018 (1)
  Occurrence 1018 (3)
  Anatomy 1018 (3)
  Pathology 1018 (3)
  Etiology 1018 (4)
  Symptoms 1018 (5)
  Prophylaxis 1018 (5)
  Treatment 1018 (5)

Ingrowing nail (onyxis, onychia, onychauxis, onychogryphosis, unguis incarnatus) is the term applied to that condition in which the lateral edge of the nail has become imbedded in the adjacent soft parts of the lateral nail groove. This may be, and usually is, followed by infection and inflammation of the soft parts with ulcer formation.

Occurrence. While this condition may be encountered on the fingers, it is most commonly found involving the toes and more especially the great toe. The external border is more frequently affected than the internal border.

Anatomy. A nail is a portion of the epidermis modified for special function. It has a root which is implanted into a groove in the skin; a body which is the exposed portion; and a free edge. The section of cutis beneath the root and body is called the matrix, because it is the part from which the nail is produced. The nail grows from the thick layer of epithelial cells above and below the nail, the layer above extending nearly to the reflection of the skin, and that below to the white semilunar line. The root and underlying matrix extends about one-half centimeter behind the exposed portion. This fact is of importance when the question of treatment is considered. The cuticle is attached to the surface of the nail in advance of its root and to its under surface a little behind the free edge. The successive growth of new cells at the root and under surface of the body causes the nail to advance forward and maintain its shape. The great toe nail takes about six months to travel its entire length.

Pathology. The term ingrowing nail gives a wrong impression of the actual pathology which really consists of an overgrowth or overfolding of the skin and soft parts around the nail edge. The soft parts are first moulded along the lateral edge of the nail, there is some bulging of the dorsal portion of the paronychia, the transverse arch of the nail and the nail and the nail matrix become exaggerated, and eventually, with continuation of pressure the nail edge cuts through the skin and infection begins.

It is important to note that the deformity involves the nail matrix as well as the nail itself as this explains the failure of any treatment which only removes the nail. With repeated infections and ulcer formation a chronic paronychia results and if neglected may go on to cellulitis of the toe and — rarely — osteomyelitis of the terminal phalanx. (Fig. 1.)

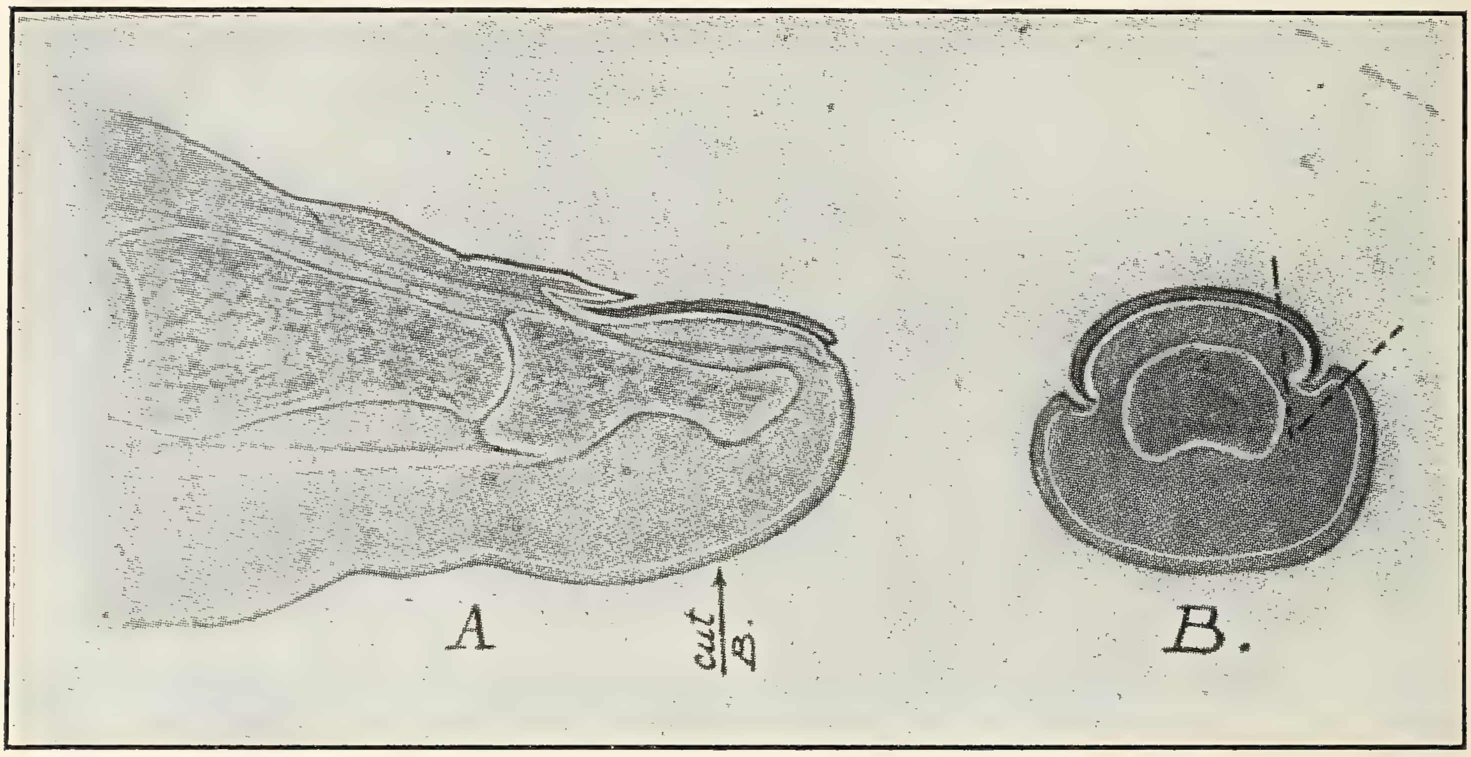

Fig. 1. Normal toenail in longitudinal (*A*) and transverse section (*B*). The dotted lines in the latter mark out the portion of the nail and matrix which should be removed.

Etiology. In the rare cases involving the fingers ingrowing nail generally occurs as a result of some occupational trauma. It is said to occur at times in wood carvers, professional potato peelers and oyster openers. It also in both fingers and toes may be due to some trophic disturbance such as Raynaud's disease or Thromboangeitus obliterans. There may be a congenital tendency which favors the development of the condition. The nail may be curved sharply sideways or flat and bent sharply at the lateral edges, or movable with its free edge extending far back or the toe may be broad with the skin growing up at the sides.

Another contributing factor may be defective hygiene such as allowing the accumulation of epithelial debris under the lateral edge of the nail. Lack of cleanliness or forcibly pulling out a still adherent clipping may help to complicate the condition by infection. Trauma such as frostbite or crushing injuries may have the same effect.

Improper clipping of the nails is a very important factor. The nail should be cut squarely across the end leaving the distal corner long so that it may override the soft parts.

The direct cause in the majority of cases is the wearing of improperly fitted shoes or stockings. Too short stockings may severely compress the toes. High heeled and narrow pointed shoes cause lateral compression. The condition is unknown in those races whose members habitually go barefooted.

Symptoms. The only symptom is pain which varies in severity with the progress of the condition. In the uncomplicated condition before infection or ulceration has taken place, the pain is present only under pressure and disappears when the offending shoes or stockings are removed. With the onset of infection, however, the pain is persistent and is made worse by the application of pressure.

Prophylaxis. The wearing of properly fitted shoes and stockings and the proper trimming of the nails are the most important factors in prophylaxis. In those individuals with a congenital predisposition to the condition, the occasional thinning of the entire body of the nail by a small emery wheel may prove of benefit. This makes the keystone of the nail arch soft and flexible and promotes outflaring of the sides of the nail.

Treatment. The treatment varies with the stage of the condition. The first step of course is to remove the cause and see that the patient is furnished with properly fitted shoes and stockings. In the uncomplicated condition, before the onset of infection or ulceration, efforts are made to lift up the corner of the nail by inserting pledgets of cotton underneath, which both lift the corner and push back the soft parts from contact with it. The nail corners should be allowed to grow long so as to overlap the soft parts. Mickel suggests the use of gauze soaked in celluloid or thin strips of gutta percha laid under the edge of the nail. The lateral edge of the nail may be lifted by fastening the end of a thin strip of adhesive plaster under it and fastening the other end around the opposite side of the toe. Foote mentions a silver hook designed to accomplish the same result. The center of the nail should be thinned as suggested under prophylaxis.

As commonly seen by the surgeon the condition is already complicated by infection and ulceration together with a foul discharge. If this is severe and acute it is wise to attempt to allay the inflammation to some extent by the application of warm wet dressings (saline or boric acid) for forty-eight to seventy-two hours, before proceeding to operation. The various operations devised have as their object either or both of two results: (1) to remove the flesh from the edge of the nail, (2) to remove the edge of the nail from the flesh. Under the first heading comes the Cotting operation which consists of shaving off all that portion of the soft part of the toe external to the lateral edge of the nail. This has been modified by Ney who first turns back two pedicle flaps of skin, removes the soft tissue and then fastens the skin back in place — thus cutting down the healing time. This operation of course leaves a permanently deformed toe. (Fig. 2.)

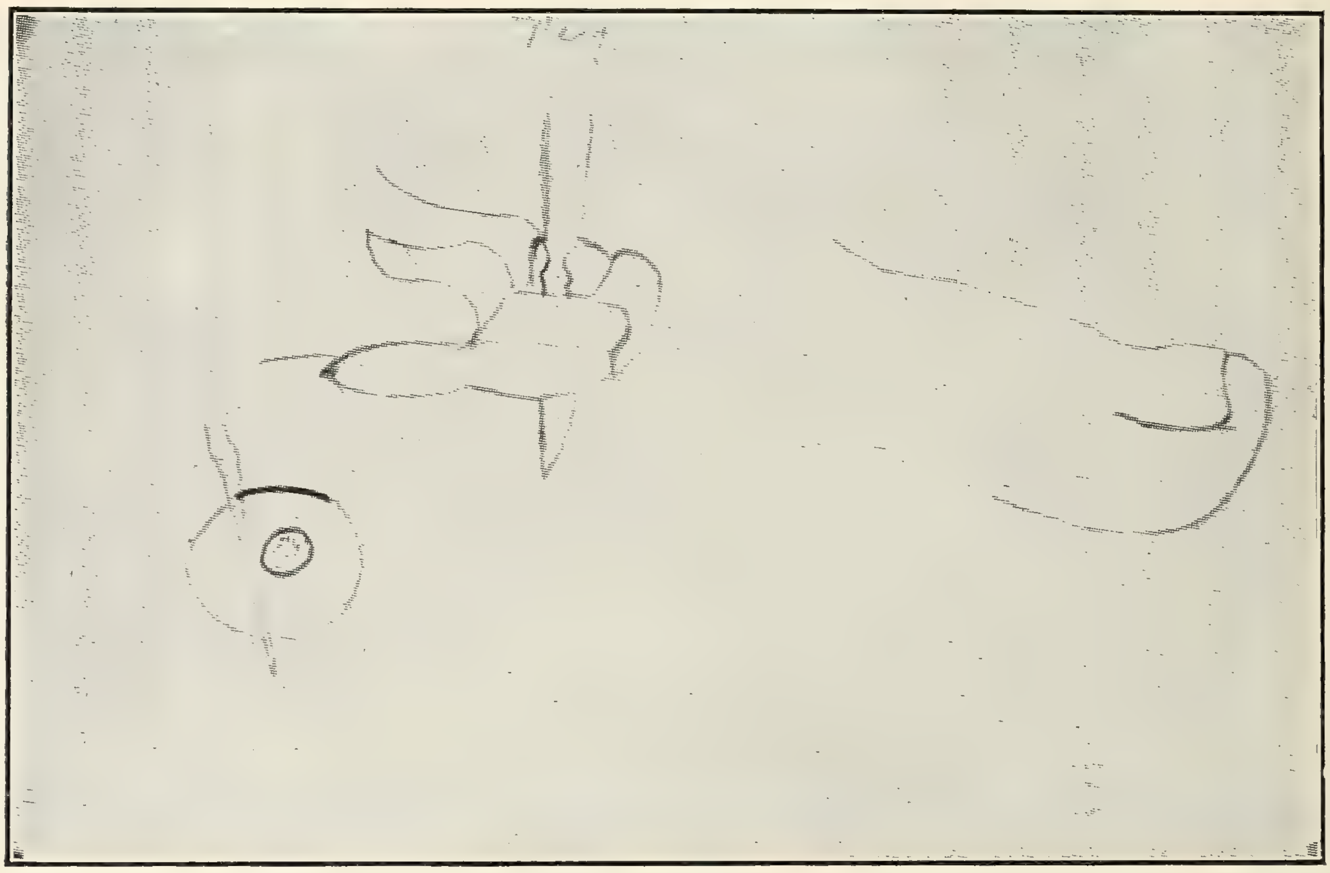

FIG. 2. Operation as modified by Ney. *A*, showing skin flap turned back and soft part to be removed. *B*, showing operation completed.

The operation in most general use is that described by von Bergmann. A lateral curved incision is made below the ulcerated skin, extending about one-half centimeter back of the nail fold. From the latter point a straight incision is made directly forward through the nail and the tissues excised, being careful not to leave any matrix or nail at the side or upper angle. The edge of the skin is then applied and held by the dressing against the cut edge of the nail. This procedure is done under local anesthesia and a small tourniquet around the toe above. Under favorable conditions the patients should be able to wear a properly fitted shoe in about ten days time. Foote and more recently Winograd have described a modification which removes only the nail and matrix leaving the soft parts, even though inflamed, to fill in the defect. If properly done this operation is effective and is the one recommended;

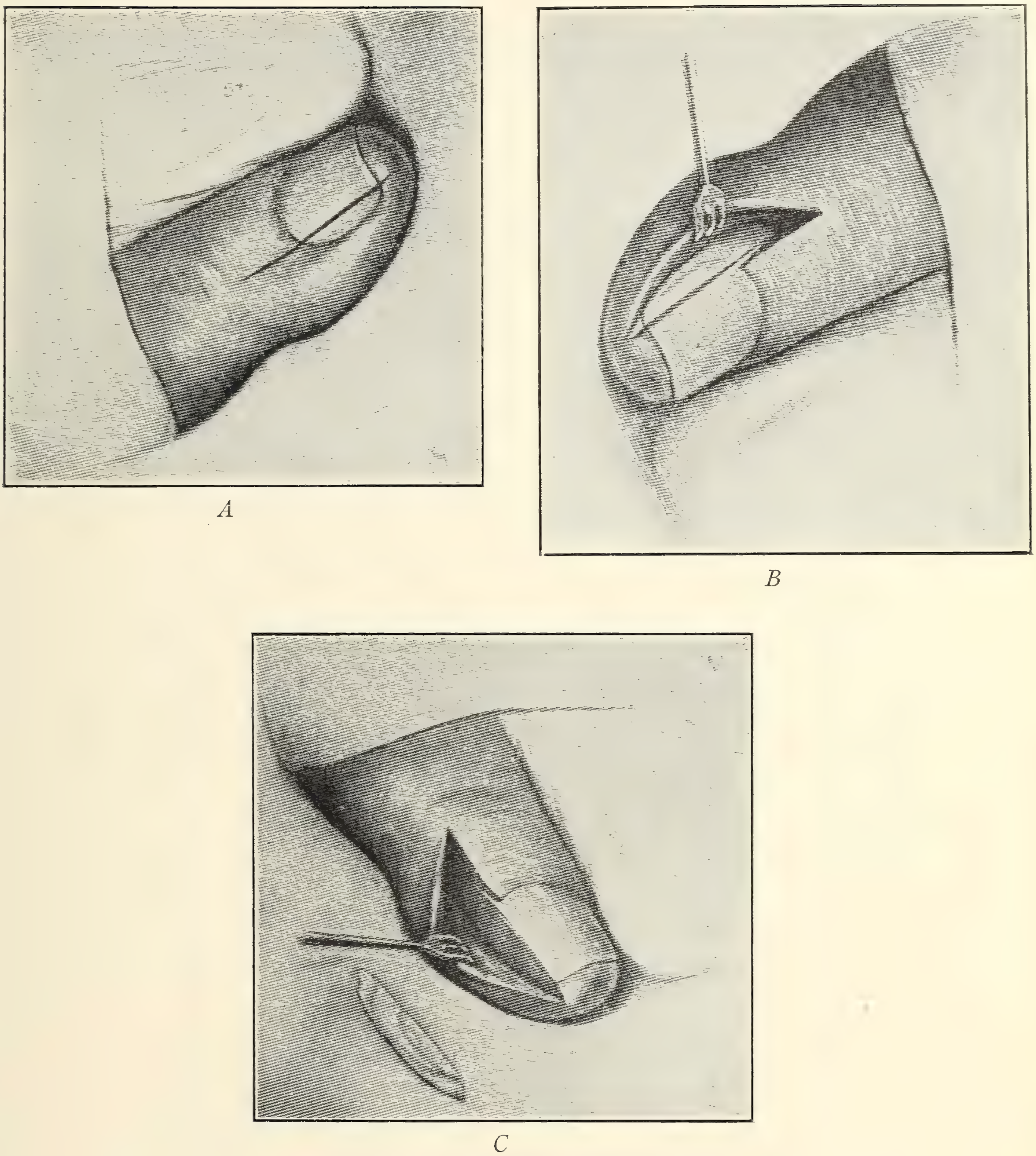

Fig. 3. Operation recommended for Ingrown Nail. *A*. The line of incision. *B*. The skin flaps reflected. *C*. The section of nail and corresponding matrix removed.

the most frequent cause of failure being the leaving of a small portion of matrix at the corner, in which case a small spur of nail will grow and cause a recurrence of symptoms. (Fig. 3.)

Condition of the patient should be investigated and trophic conditions and diabetes in particular should be looked for and treated if found.

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RECTAL SURGERY WITH SPECIAL REFERENCE TO LOCAL ANÆSTHESIA

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Historical. The discovery of the anæsthetic effect of cocaine in the eye by Van Anrep in 1879 and its actual use as an anæsthetic for operation upon the eye by Kohler in 1884 were the work of pioneers in the field of local anæsthesia. Corning's observation that the effect of cocaine was enhanced when used in a field made bloodless by a constrictor was of almost equal importance to his original investigation on spinal anæsthesia in 1885. Halsted's research on the blocking of the inferior maxillary nerve by local injection of cocaine around it and Crile's nerve block by endoneural injection were real advances which led to Schleich's work in 1891 on infiltration of tissues with weak solution of cocaine combined with hypotonic solutions of indifferent salts. Hackenbruch's advocacy of circular anæsthesia, by which principle the field of operation was surrounded by a local anæsthetic medium, thus blocking the nerves entering the field of operation without making necessary the injection of anæsthetic in the operative field itself, was a most important advance and is a principle very largely used to-day. The discovery of novocaine in 1905 by Einhorn and the elaboration of the principles underlying local anæsthesia, including the use of adrenalin combined with novocaine by H. Braun, were monuments in the progress of the extension of the field of local anæsthesia.

PROPERTIES OF NOVOCAINE

The qualities of a good local anæsthetic, as advanced by Braun, are (1) low toxicity, (2) lack of irritation to tissues, (3) solubility in water, (4) capacity for sterilization without deterioration, (5) compatibility with adrenalin. In these respects novocaine qualifies as the best drug for local anæsthesia.

While novocaine has only about one-third of the anæsthetizing strength of cocaine and the duration of the anæsthesia from novocaine is only one-tenth that of cocaine, these defects are apparent rather than real because the addition of adrenalin to novocaine lengthens very materially the duration of the anæsthesia and the low toxicity of novocaine allows the use of stronger solutions than are permissible when using cocaine.

Novocaine has no irritating effect on tissues into which it is injected.

Novocaine is about one-tenth as toxic as cocaine and can, therefore, be used in much larger doses. The toxic symptoms from novocaine are lowering of the blood pressure with consequent pallor, palpitation, sweating, restlessness, sense of oppression and dizziness. These toxic symptoms rarely develop in infiltration or circular anæsthesia, but have been most observed in paravertebral, plexus, Gasserian ganglion and extradural anæsthesia. In several thousand infiltration and circular anæsthesias with ½ per cent novocaine combined with adrenalin, where up to 200 c.c. of the anæsthesic solution was used, the author has never seen any serious toxic manifestations. Palpitation in a moderate degree is experienced by about 30 per cent of the patients and pallor and sweating are observed in perhaps 10 per cent. As these symptoms may also occur in nervous individuals put in unusual surroundings and undergoing strange experience, it is not possible to state what proportion are effected by novocaine alone. Suffice it to say that 150-200 c.c. of ½ per cent novocaine combined with adrenalin may be used with safety.

Adrenalin added to novocaine solution in the ratio of 2 minims of adrenalin to one ounce of ½ per cent novocaine solution is sufficient to cause an anæmia of the field of injection which prolongs the effect of the anæsthetic, makes its absorption into the circulation less rapid, thereby lessening the possibility of toxic effects, and reduces the amount of bleeding in the field of operation. Not more than ten minims of adrenalin should be used. Sterile adrenalin, 1-2,000, coming in ampules and withdrawn with a sterile minim syringe, is to be recommended because of its sterility and uniformity of strength. Adrenalin in bulk deteriorates on standing.

The novocaine dissolved in sterile water or in 0.9 per cent salt solution, is sterilized in small Ehrlmeyer flasks by boiling. Care should be taken that no alkali be present in the flask, as this deteriorates the adrenalin which is added after the novocaine solution is cooled.

Extreme care should be taken in every operating room that the novocaine solution be kept in distinctive bottles. Fatal accidents have followed the use of other colorless solutions which were supposed to be novocaine. Likewise if the novocaine is dissolved in salt solution, caution should be used that it be 0.9 per cent and not a stronger salt solution such as is often kept in operating rooms and known as "stock salt solution," to which any required physiological strength may be given by adding water. The use of the strong salt solution (15 per cent or more) as an injection into the tissues will cause a massive slough. The careful preparation of novocaine solution is essential to satisfactory results from its use.

INFILTRATION AND CIRCULAR ANÆSTHESIA

Infiltration anæsthesia is induced by direct injection of the novocaine into the field of operation and acts by its direct effect on the nerves in that area. This injection causes a swelling of the tissues affected and has certain disadvantages in rectal surgery, where a distortion of the affected tissue may obliterate valuable landmarks.

Circular anæsthesia (Hackenbruch) involves the principle of injection of the novocaine solution around the field of operation and not directly into it, reaching the nerves that supply the operative field before they enter it. This type of anæsthesia is particularly adaptable to many rectal operations because it successfully blocks numerous small branches of the internal pudic nerve before they reach the lower bowel and at the same time does not make an edematous distorted operative field. It also allows the operator to inject the anæsthetic medium into a field that can be rendered relatively sterile by surgical preparation. The anæsthesia thus obtained is practically always certain and complete, comparing favorably with other types of local anæsthesia for the rectal regions where a certain definite percentage of failures result and where the anæsthesia produced includes not only the rectum and anus but the perineum, genitalia or still larger fields. I refer to sacral, parasacral, and post-sacral anæsthesia.

Especial advantages of local anæsthesia in minor surgery of the rectum and anus are the decided lessening of hemorrhage during operation, the absence of straining on the part of the patient with consequent soiling of the field or engorgement of vascular tumors, and, finally, the feasibility of relief of local pathology in patients handicapped by constitutional disturbances precluding the use of a general anæsthesia.

As contra-indications for its use may be mentioned acute or widespread infection around the anus, lack of proper apparatus, lack of time on the part of the operator, or nervous instability on the part of the patient such as would make an average amount of cooperation between the patient and the operator impossible.

CIRCULAR ANÆSTHESIA OF THE ANUS AND RECTUM

Preparation of the Patient. The evening before the operation and again two hours before it, the patient is given an enema of one pint of lukewarm water.

The perineal and gluteal regions are shaved. The operative field is scrubbed with soap and water.

Regular diet is given excepting only food containing hard, sharp particles such as seeds or bran, which are indigestible and capable of causing trauma.

No preliminary sedative is given, as it has been found that vomiting occurs in about 20 per cent of the patients having preliminary sedatives.

Position of the Patient. The patient is in position for lithotomy, with the knees resting in supports that present excessive flexion of thighs and discomfort from pressure.

Apparatus. A 10 c.c. record syringe with a right-angled adaptor allows the needle to be introduced into different planes by simply rotating the syringe and at the same time permits the operator's hand holding the syringe, to be out of the line of vision in the field. Three lengths of record needles are used; a small size for intradermal wheals, and a 5 cm. and 10 cm. length for deeper structures. These needles must be kept sharp and free from rust. Thorough cleaning with ether after use and the introduction of an oiled wire in the lumen of the needle preserves them.

Anatomy. The anal region and rectum are supplied by the second, third, fourth, and fifth sacral nerves and the coccygeal plexus. The internal pudic nerve gives off the inferior hemorrhoidal, which divides into many branches in the ischiorectal fossa and supplies the external sphincter muscle and the integument about the anus and anastomoses with the perineal nerves and the perineal branches of the cutaneous femoris posteriores, which supply the perineum. There are also sympathetic fibers from the hypogastric plexus and pudental plexus forming a plexus which is sub-peritoneal and just above the levator ani muscle. The practical significance of the nerve supply in regard to anæsthesia by injection is that there are many nerve fibers entering the field and that the most sensitive area is the region of the mucocutaneous line in the anus.

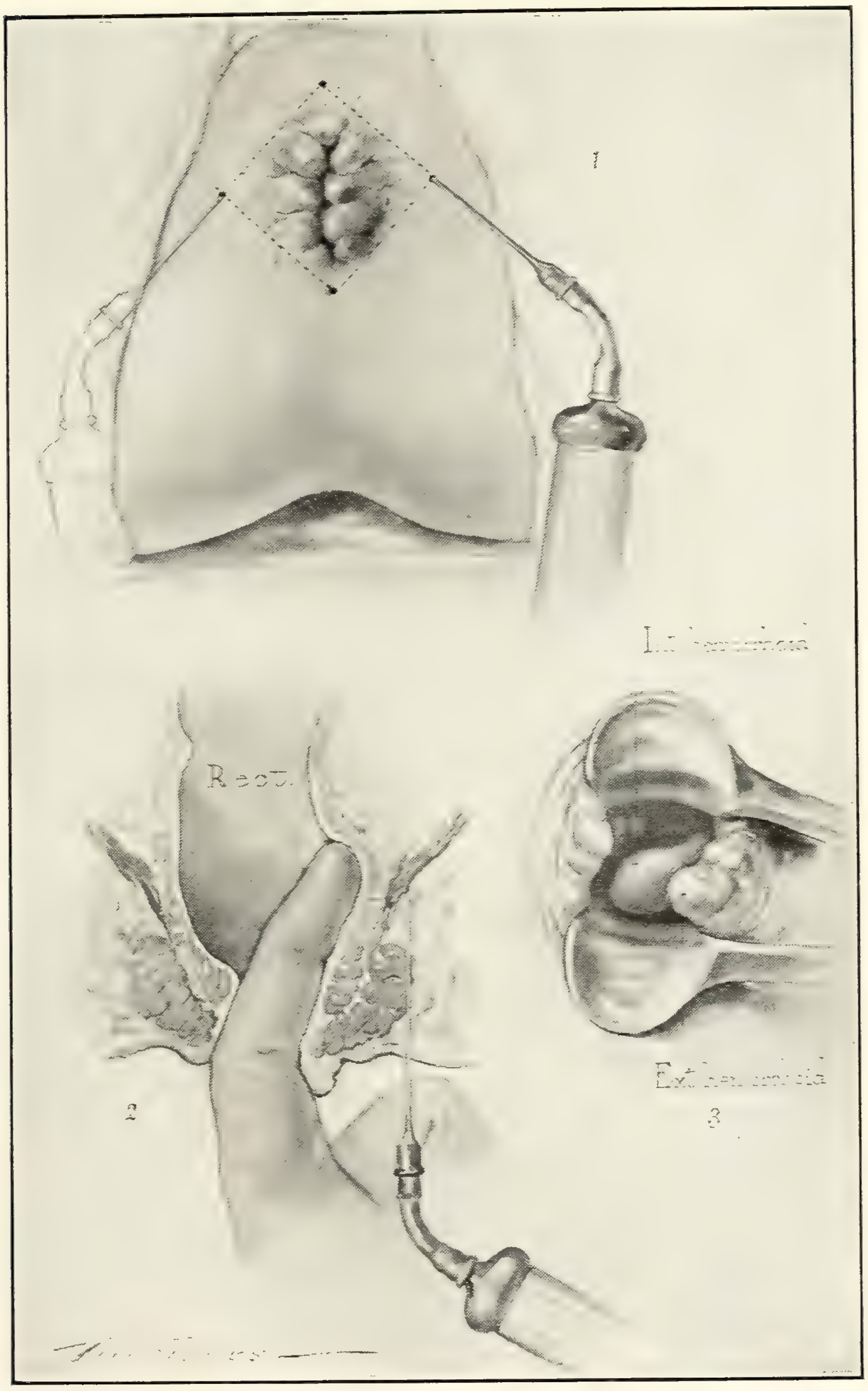

PLATE 402. LOCAL ANÆSTHESIA FOR INTERNAL AND EXTERNAL HEMORRHOIDS

1. Four black points represent *intra* dermal wheals made by injection of ½ per cent novocaine into the papillary layer of skin. Dotted lines represent *sub*-cutaneous injection of novocaine connecting these wheals.

2. Left Index finger hooked around internal sphincter. Long needle passing through an intracutaneous wheal, through peripheral fibers of external sphincter muscle to the level of the levator ani. This injection is carried out through all four wheals around the circumference of the lower rectum.

3. Speculum dilating rectum showing internal hemorrhoid and external cutaneous hemorrhoid with mucocutaneous line between them.

TECHNIC OF CIRCULAR ANÆSTHESIA ABOUT THE RECTUM

With the finest needle *intra*dermal wheals are raised about two fingers in breadth from the anus on the right and left side (Plate 402, Fig. 1). The production of these wheals is painful and the patient should be warned of the needle puncture. These white wheals raised in the skin produce an instantaneous pressure anæsthesia and can be used as sites for reintroduction of other needles without pain to the patient. The 5 cm. needles are now put on the filled syringe and introduced by way of one of the lateral wheals through the skin into the subcutaneous tissue. Novocaine is then injected under the skin with the needle advanced first toward the perineum and then toward the coccyx. The process is repeated for the other side. About 30 c.c. of anæsthetic are used for the complete subcutaneous circular injection. To inject this fluid without pain to the patient it is necessary to keep the plunger of the syringe in constant motion in order that a pressure anæsthesia may be produced in front of the advancing needle. The point of the needle should be kept in constant motion in order that the anæsthetic may be evenly distributed and no great amount be injected into a vessel should one be punctured. This procedure should take about five minutes and should be conducted slowly and with perfect coordination, as sudden or nervous movements are apt to alarm the patient.

The 10 cm. needle is now put on the syringe. The left index finger is lubricated and introduced through the anal ring until the tip of the finger can be gently hooked around the upper border of the internal sphincter, which lies just below the easily palpated levator ani insertion. The long needle is now inserted through one of the lateral wheals and pushed upward just outside of the margin of the external sphincter muscle; and anæsthetic solution is constantly injected until the end of the needle is about opposite the finger in the rectum (Plate 402, Fig. 2). The needle is not palpated by the finger in the rectum as it is about half an inch away from the bowel. The needle is now withdrawn so that the syringe may be filled by an assistant. The index finger remains in the rectum until the anæsthesia is completed. The same process is now repeated through the same wheal except that the point of the needle inclines first anteriorly and then posteriorly so that a wall of anæsthetic is produced on that side. This process is now repeated on the opposite side, using on each side almost one ounce of ½ per cent novocaine-adrenalin solution. The skin over the perineum is now insensitive from the anæsthetic which was injected subcutaneously at the start, so the long needle is now introduced just in front of the anus and about 5 cm. injected between the sphincter and perineal muscle anteriorly. A posterior puncture is also made and about 10 c.c. of anæsthetic injected just outside of the sphincter muscles. The deep injections will occupy about ten minutes of time and will consume about three ounces of ½ per cent novocaine solution.

Before inserting the needles, the skin is bathed with an alcohol sponge to insure continued asepsis.

The operative field should now be anæsthetic. More features of this technic will be taken up later when special operations are considered.

If the adrenalin used is active and not deteriorated the anæsthesia will last about two and one-half hours.

INTERNAL AND EXTERNAL HEMORRHOIDS

As hemorrhoids are often regarded as the cause of practically all symptoms occurring in the rectum, it is well to define clearly the usual symptoms they produce, at the same time emphasizing the fact that many symptoms complained of are caused by lesions other than hemorrhoids.

The symptoms of hemorrhoids are (1) bleeding of bright red blood at stool, (2) later, bleeding and protrusion at stool, (3) still later, bleeding and protrusion not only at stool but at any time the patient is on his feet. Discomfort from protrusion and soreness of the protruding mass then develop. Other conditions more or less associated with hemorrhoids are constipation and dermatitis ani.

Actual pain is absent unless complications are present. The most common complication is thrombosis of the veins under the anal skin, causing a sudden irreducible protrusion accompanied by constant pain and great tenderness on pressure over the swelling. Owing to the involvement of several small veins in the thrombosis edema in the lower anal tissue develops and this is often sufficient to cause a protrusion of the internal hemorrhoids by traction. If this mass becomes strangulated in the grasp of the anal sphincter and irreducible because of edema and further increase of the thrombosis, it may undergo necrosis and slough off. The infection accompanying such procedure carries with it a danger of general infection, but loss of life seldom occurs.

The degree to which this condition develops varies from a small shot-like thrombosis under the anal skin with practically no symptoms to the extreme degree of necrosis of the lower bowel pictured above.

Other complicating factors causing pain in hemorrhoids are ulceration of the surface of the internal hemorrhoids from injudicious applications of medicines of different sorts, persistent diarrhœa, or superficial diffuse ulceration of constantly protruding internal hemorrhoids. None of these factors are commonly present, so that marked rectal pain when thrombosis is absent is usually due to some other factor, such as ulcer in the rectum, abscess formation, carcinoma, etc.

Treatment. Assuming that cirrhosis of the liver, passive congestion from heart lesions, pelvic tumors, and other persistent causative factors are ruled out, internal and external hemorrhoids are best treated by operation. In very anæmic or debilitated patients where operation is contra-indicated, bleeding may be stopped by local applications of 2 per cent silver nitrate solution to the mucosa over the varicose veins, by electrolysis with an electric needle introduced into the internal hemorrhoid, or by injection of 55 per cent carbolic acid in glycerine or olive oil. Both of the latter agents produce a thrombosis in the internal hemorrhoid.

Operative treatment is the safest procedure and gives permanent results if thoroughly done. About 90 per cent of the operations may be done under local anæsthesia as already outlined.

Any operative procedure for a lesion such as hemorrhoids should (1) be safe and free from complications, (2) eradicate the whole pathology, (3) have a rapid convalescence, (4) preclude frequent recurrence.

A self-retaining bivalve speculum (Plate 402, Fig. 3) is introduced into the rectum and lateral dilatation of the sphincters is carried out. This is done slowly; five minutes are allowed for it in order to preclude injury to the sphincter muscles. A sense of pressure is experienced by some patients, but pain is absent if the anæsthetic has been thoroughly injected. After the hemorrhoids have been located, the least accessible internal hemorrhoid is picked up by a Kocher forcep, which is given to an assistant to hold. The skin beneath the hemorrhoid is picked up by a tissue forceps and a small strip of it is removed from the top with scissors (Plate 403, Fig. 1), so that the parallel incisions removing it are carried up to the mucocutaneous line just below the internal hemorrhoid which is in the grasp of the Kocher forceps. (Plate 403, Fig. 2.)

A hemorrhoid clamp (Plate 403, Fig. 3) is now placed under the strip of skin just dissected up to grasp the internal hemorrhoid so that the deeper layers of the bowel wall shall *not* be included. The clamp is now surrounded by damp gauze and the hemorrhoid above the clamp is burned off by a dull red point of an electric cautery. (Plate 403, Fig. 4.) The clamp is now removed. The fine eschar represents the former site of the internal hemorrhoid. (Plate 403, Fig. 5.) Exterior to this is the denuded area resulting from removing the strip of skin over the skin tag. Through this area the varicose veins under the skin tag are dis-

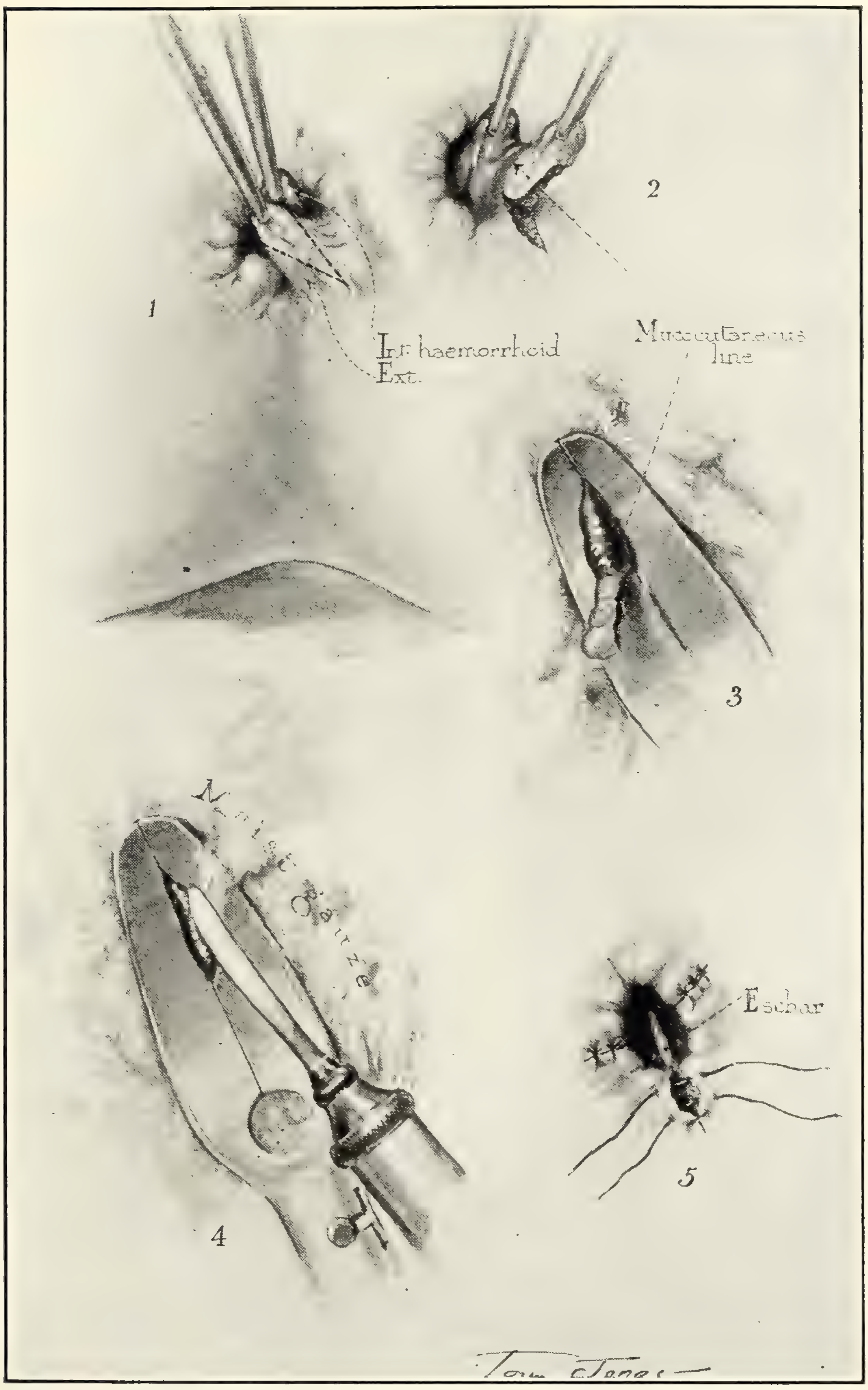

Plate 403. Operation for Internal and External Hemorrhoids

1. Forceps on internal and external hemorrhoids. Incision made in skin of external hemorrhoid by scissors along dotted line.

2. External hemorrhoid lifted from its bed showing incisions freeing it extending to mucocutaneous line.

3. Clamp applied to internal hemorrhoid in axis of bowel from which external hemorrhoid was dissected free.

4. Cauterization of internal hemorrhoid down to clamp so cautery line and clamp line are nearly in same plane.

5. Suture of skin incisions by interrupted triple O iodine gut with knots cut very short.

sected out. This causes the skin tag to collapse, so that the incisions made in removing the skin now lie together. The skin is closed by interrupted fine catgut with the knots cut very short so that the sutures will untie in a few days and come out. (Plate 403, Fig. 5.)

This procedure for removal of the internal hemorrhoid by clamp and cautery and the external hemorrhoid by dissecting out the varicose veins within it, is repeated wherever internal and external hemorrhoids are present. It should be remembered that only redundant tissue is included in the clamp and that no sutures should be placed in the skin that will in any way compromise the diameter of the anal opening. This latter result is made possible by the removal of small strips of skin over the skin tags, accompanied by thorough dissection of the varicose veins under them. Usually three to six hemorrhoids are removed.

No packing or tubes of any kind are left in the rectum, for hemostasis should be complete when the operation is over.

A moist compress is held *tightly* over the anal region by a "T" bandage.

After Care. Heroin, gr. 1/12, is given hypodermically as soon as the local anæsthetic wears away. Usually one dose is all that is required.

Warm moist compresses are renewed every few hours.

An anti-constipation diet of raw and cooked fruit and coarse vegetables is given; but fruit with seeds and bran should be excluded.

A bowel movement is induced the day following operation and every day thereafter by an enema of two ounces of oil and one pint of water given through a soft catheter. Following the movement, a warm sitz bath is given and moist compresses are re-applied.

Covering the anal region with zinc oxide ointment gives relief.

The patient is up on the second or third day and leaves the hospital usually about five days after the operation.

Enemas are kept up for two weeks from the day of the operation.

Washing of the operative field with castile soap and water twice a day results in primary healing of the skin edges in about 80 per cent of the cases.

The average patient is back at work in a week and is completely healed in ten days to two weeks.

Mortality should be nil. One patient was lost from an excessive slough with later developing peritonitis due to the injection of strong salt brine which was used by error in making up the anæsthetic. One patient died ten days after operation in coma from a cirrhosis of the liver that was practically without symptoms or findings prior to operation. These fatalities occurred in a series of over two thousand cases.

Complications are usually absent. Bleeding after operation occurred in only one patient, who bled from an external skin edge which was inadequately sutured. Ascending infection involving the portal vein has never been seen by the author. Infection of sutured skin edges occurs very rarely.

Fissure in ano developing in the site of removal of anal skin rarely occurs. Infection of the ischiorectal space from the injection of the novocaine solution has never been observed except in the one case noted. Stricture, incontinence of sphincters, extrophy of mucous membrane, which is so often seen after Whitehead operations, never occurs.

THROMBOSIS OF ANAL SKIN

If the swelling involves only one side and is unassociated with prolapse of the internal hemorrhoids, the clots can be evacuated. From 3 to 5 c.c. of ½ per cent novocaine are injected directly into the swelling so that the skin becomes tense over the thrombosis (Plate 404, Fig. 1). An incision with a scalpel is now made directly into the mass. The edges of the mass are cut away by scissors 2 to 4 mm. on either side (Plate 404, Fig. 2). The clotted varicose veins are picked up and dissected out (Plate 404, Fig. 3). The swelling then disappears (Plate 404, Fig. 4), and the skin edges can be sutured; care being taken to include the bottom of the wound in order that no dead spaces shall be left in which a hematoma may form. If the patient is ambulatory, a small strip of gauze is packed between the edges of the incision and a "T" bandage is applied. The after-care is the same as just described in the case of internal and external hemorrhoids. If the thrombosis is on all sides, or is associated with prolapse of internal hemorrhoids, an operation for relief of the whole condition as described for internal and external hemorrhoids is indicated.

CHRONIC FISSURE IN ANO. TRAUMATIC ULCER.

One of the most frequent and certainly the most distressing of non-malignant lesions of the rectum is the traumatic ulcer, or, as it is generally known, fissure in ano. This lesion is a fissure in appearance because it lies in the grasp of the contracted spasmodic sphincter muscles, but when viewed after relaxation of these muscles, is a defect averaging in area the size of a dime. In contrast to these veritable ulcers are the super-

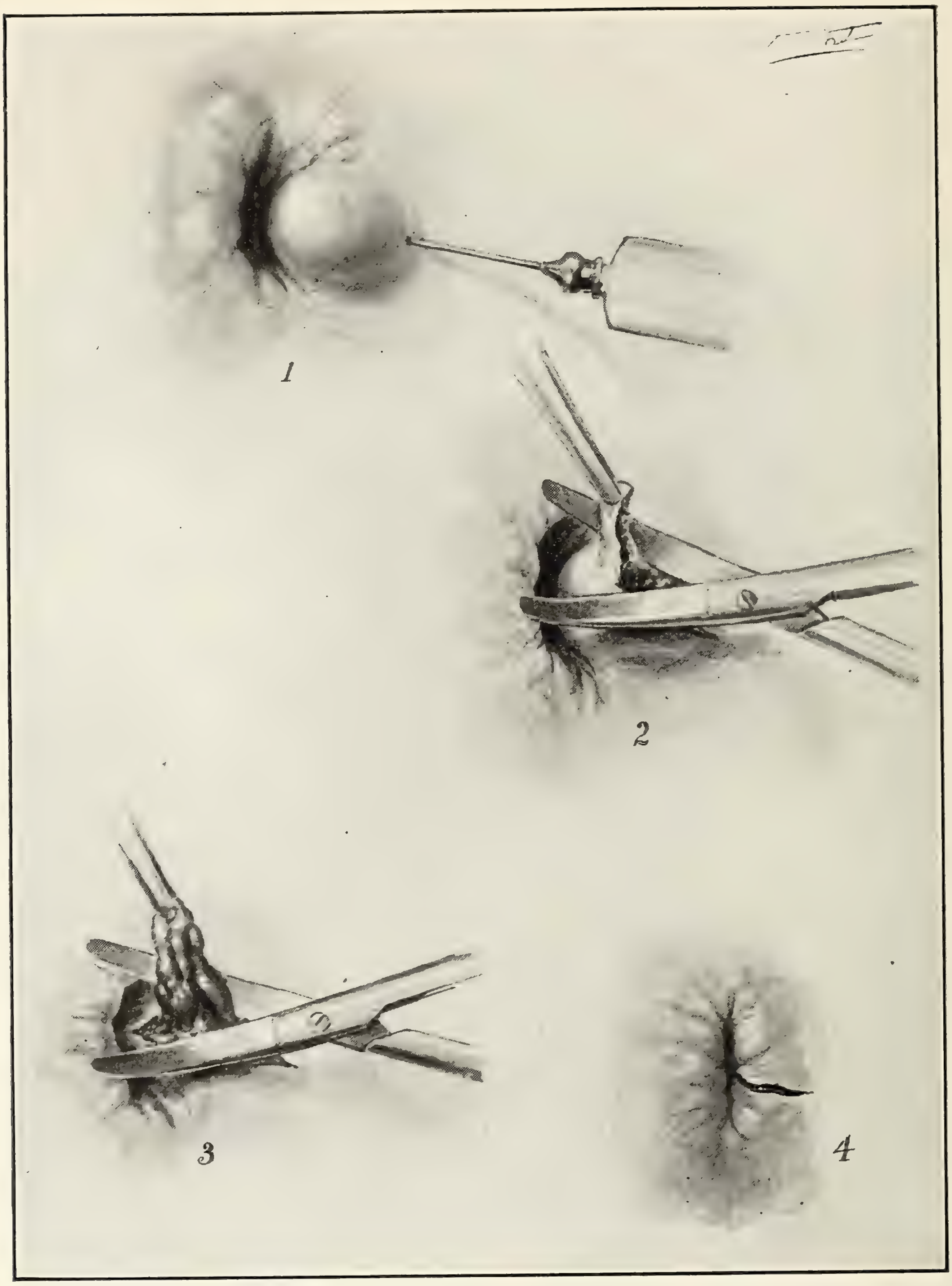

Plate 404. Thrombotic External Hemorrhoid Removed Under Local Anæsthesia

1. Injection of ½ per cent novocaine directly into thrombotic hemorrhoid until it is distended.

2. Excision of small strip of skin over the swelling. Excision in radial axis of bowel.

3. Removal of thrombotic veins.

4. Collapse of swelling with linear incision left to granulate.

ficial longitudinal tears which are also traumatic in origin but which heal within a few days and do not run a subacute and chronic course. These latter lesions may be justly compared to a superficial abrasion of the skin in any region of the body, while the chronic ulcers, or so-called fissures in ano, often resemble duodenal ulcer, in shape and size, though they rarely have the same amount of induration about their base.

The origin of these traumatic ulcers of the anorectal region is clear and is dependent to a great extent on the anatomy of the mucocutaneous line in the rectum. It will be remembered that this mucocutaneous junction is the seat of the small depressions known as sinuses of Morgagni, between which are small, sometimes elevated papillæ. The passage through the rectum of a constipated movement or of hard vegetable or seedy material is liable to cause a break at the mucocutaneous line, which enlarges in all directions a sinus of Morgagni, one of the normal depressions at the mucocutaneous line. This produces a miniature blind fistula with the opening at the mucocutaneous line and with the fistulous tract running down under the anal skin. If the trauma causing the lesion is unusually severe, the skin covering the miniature fistula may be split open at the same time. Infection now takes place in the blind fistula, and this may be somewhat chronic and be largely caused by the presence of a seed or some other small foreign body which finds its way into the blind fistula through the opening at the mucocutaneous line. This infected blind fistula is the forerunner of the ulcer which develops when the skin over the fistulous tract is ulcerated through by reason of the infection under it or is broken through by a hard bowel movement. An infected ulcer is then produced with undermined edges corresponding to the ramifications of the fistula under it. The ulcer or fissure, therefore, is but part of the lesion, and if a fishhook probe is inserted at the mucocutaneous line above the ulcer, it will often enter the original opening of the blind fistula and come out at the ulcer below it. (Plate 405, Fig. 1.) If the fishhook probe is inserted at the ulcer, it will continue downward under the skin not infrequently from one to three centimeters. (Plate 405, Fig. 2 "C".) The longer the lesion has existed the more scar tissue will be found about it, so that finally, by healing and breaking down of the ulcer, a firm scar tissue base and edge of the ulcer will be formed. The lower end of the blind fistula beneath the ulcer often becomes inflamed and an inflammatory fibroma develops which has been called a "sentinel pile." (Plate 405, Figs. 1 and 2 "B.") Into this inflammatory fibroma the lower end of the fistula runs. At the mucocutaneous line another squamous covered fibrous polyp may develop (Plate 405, Figs. 1 and 2 "A").

Owing to the development of this lesion in the grasp of the sphincter muscles, a spasm of these muscles develops. This is responsible for the symptoms which are due to the irritation of the ulcer by reason of the passage of the bowel movement through the narrowed anal canal. Severe smarting and burning pain lasting from a few minutes to a whole day comes after the bowel movement. If there is much pus discharge from the ulcer, a dermatitis ani develops. Bleeding may occur from the ulcer during bowel movements. Reflex symptoms such as bladder irri-

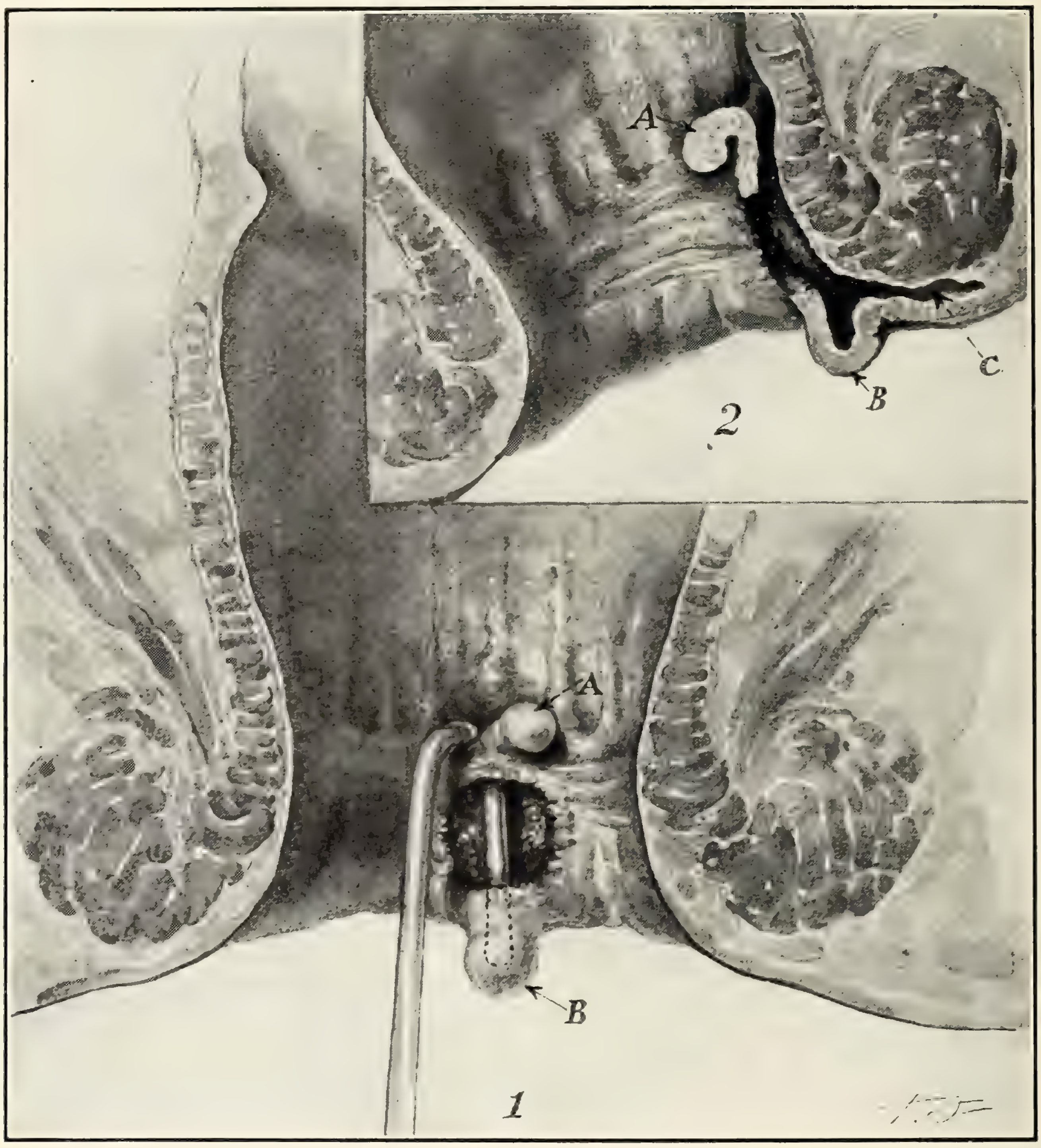

Plate 405. Chronic "Fissure in Ano" (Traumatic Ulcer)

1. Fishhook probe entering fistula at mucocutaneous line. "A" inflammatory fibrous polyp overlying opening of fistula, with ulcer distal to it. "B" "sentinel pile" (inflammatory fibrous polyp) near the end of blind fistulous tract.

2. Cross section through region of the ulcer showing "A" polypus at internal opening of fistula with the ulcer beneath it, "B" the "sentinel pile" and "C" the continuation of the blind fistula under the skin.

tability and even retention of urine in some instances may develop. Pain in the back and legs is common. Digestive disturbances, general nervousness and sleeplessness are commonly observed.

The treatment is simple and consists in gentle relaxation of the sphincter muscles and excision of the ulcer and the fistula below it. Local anæsthesia is usually used, the only modification from the method described for hemorrhoids being that before the finger is introduced into the rectum, as a guide for the deep injection of novocaine, 5 to 10 c.c. of ½ per cent novocaine-adrenalin solution is injected directly under the ulcer. This allows the technic to be followed without pain. If polyps have developed, they are excised. All overhanging edges of the ulcer are excised (Plate 406, Fig. 1). A single layer of gutta percha tissue three-quarters of an inch long and half an inch wide is placed in the defect resulting from excision of the ulcer and left there for twenty-four hours.

The after-care is in all essentials the same as that described for hemorrhoids.

FISTULA IN ANO

Fistulæ around the rectum with openings in the ischiorectal fossa or in the perirectal tissues are either pyogenic or tuberculous in origin.

The pyogenic type comprises the majority of the cases. The origin of pyogenic fistula in ano consists in the formation of an ischiorectal or perirectal abcess which opens, or is opened, through the skin overlying the ischiorectal fossa. The abscess originates in the wall of the rectum by reason of an infection which is usually the result of trauma obtained at bowel movement. A tear or separation of the mucocutaneous line by abnormally hard or loose bowel movements, or by a foreign body in the stool, creates a nidus of infection from which, by continuity or by spread along the lymphatics, infection is carried to the perirectal or ischiorectal fat, where an abscess forms. The opening of this abscess externally creates the external opening of the fistula and the point of injury in the bowel is usually the internal opening. The internal opening may be large, and may be the source of a pus discharge into the lumen of the bowel; but commonly it is a small opening, varying from one to three millimeters in diameter. The smaller the internal opening of the fistula, the less pus discharge occurs from it and the smaller the fistula leading from it is. Small internal openings of fistulæ predispose to recurrent abscess formation. These abscesses are most liable to reoccur after diarrhœa or constipation, when either fluid feces enter the internal opening or traumatism reinfects it. Large internal opening of the fistulæ are usually accompanied by discharging sinuses in the ischiorectal region which persist indefinitely. The position of the internal opening varies considerably and is a most important factor in the operative treatment of fistula in ano. Most commonly the internal opening is at the mucocutaneous line and occurs there because of a traumatism received during bowel movement which causes a separation of the mucocutaneous line as described in detail under "fissure in ano." At the time the traumatism is incurred, infection takes place and either by direct extension or by way

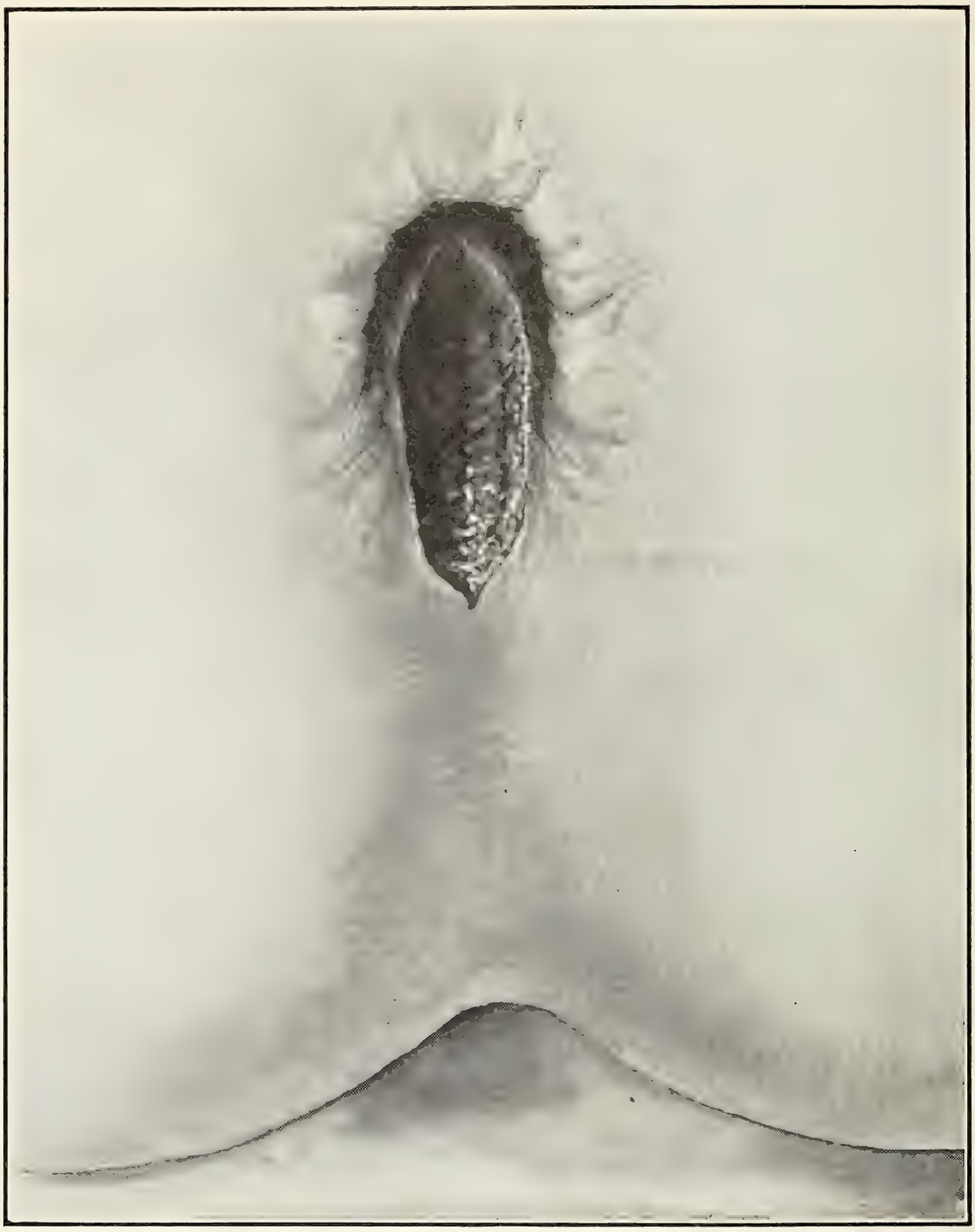

Plate 406. Chronic "Fissure in Ano" (Traumatic Ulcer)

1. Defect left after excision of pathology showing sphincter and in base of wound.

of the lymphatics is carried to the perirectal tissue. The separation of the mucocutaneous line usually occurs on the posterior wall of the bowel. It is not surprising, then, that the internal openings of most pyogenic fistulæ in ano are on the posterior wall of the rectum at the mucocutaneous line, which lies between the internal and external sphincter muscles. When by reason of an infective process occurring at any other portion of the lower bowel an abscess is formed in the perirectal tissue, the internal opening is found in the rectum at the point of injury or infection. It may be above the internal sphincter or it may be in or in rare instances, even external to the external sphincter. If the external opening of a fistula is closed by granulation tissue or by temporary healing over of the skin, a new abscess is liable to result which may rupture through the old external opening or may open at some other point. This leads to multiplicity of external openings in neglected cases, so that as many as three to ten openings may be present. In exceptional cases two internal openings may be present. If the internal openings have persisted over a number of months, it is usual to find a fibrous inflammatory polypus overlying them. The occurrence of such a polypus is useful in calling attention to the probable internal opening of the fistula.

The symptoms of a pyogenic fistula in ano are those due to the formation of the ischiorectal abscess and to the subsequent presence of discharging external sinuses.

The early diagnosis of ischiorectal or perirectal abscess may be difficult, owing to the deep position of the abscess and the absence of external evidence of it, such as redness or swelling. Where dull aching or throbbing pain occurs around the rectum, associated with malaise, backache, sleeplessness, slight temperature, a beginning abscess must be thought of as the cause. Early operation by means of an incision through the skin radiating from the bowel and the opening of the abscess by the introduction of an artery forceps is indicated. Gas anæsthesia is best used.

After the acute inflammatory stage has passed and a small discharging external opening is the only remains of the abscess, efforts should be made to discover the source of the abscess. By digital examination of the rectum the presence of a small polypus may be discovered and this is always a possible site of the internal opening of the fistula. A small fenestrated proctoscope is introduced into the rectum and a thorough examination of the mucocutaneous line is made to discover a defect from which pus is discharging or in which granulation tissue is seen. With the suspicious area in view through the protoscope, fluid may be injected through the external opening and may be seen to escape into the rectum through the suspected internal opening. A small flexible probe introduced through the external opening may be passed into the bowel through the internal opening. In some instances the internal opening may not be discovered until the operation, when anæsthesia renders the field to be examined insensitive.

As the positions of the external openings vary and the course of the sinuses is not infrequently complex, a series of examples will be given which in a general way depict the operative management of pyogenic fistulæ in ano.

BLIND INTERNAL FISTULA

The most simple in structure of all rectal fistulæ is the blind internal fistula. The formation of this fistula has been described under "traumatic ulcer" or "chronic fissure in ano," because it may be the origin of either a chronic ulcer, an ischiorectal abscess, or a fistula in ano with internal and external openings, depending on whether the infection that takes place in it spreads into the soft parts around the rectum or remains localized. The more shallow the blind fistula is, the better is its drainage, and consequently the less probable is the development of acute infection in it. At the opening of these shallow blind fistulæ at the mucocutaneous line, a fibrous polypus covered with squamous epithelium commonly develops. These polypi, which vary in size from a match-head to an inch or more in length, are often associated with symptoms. Projecting into the lumen of the bowel, they are frequently traumatized during a constipated bowel movement, so that their attachment to the bowel is torn, resulting in bleeding and pain. If several blind fistulæ capped by polypi be present, enough irritation of the rectum is caused to increase mucous formation, which, in association with the mechanical irritation caused by the polypi, may be a factor in the development of a dermatitis ani. Much has been written and over-emphasis has been placed on so-called "pockets" which develop at the mucocutaneous line of the rectum. Slight depressions in the mucosa capped by fine papillæ are normal. The blind fistulæ here described may vary from one-half inch to two inches in depth and are pathological.

In the treatment of these blind internal fistulæ, the region is anæsthetized by circular anæsthesia (Plate 402), a fishhook probe is inserted into the internal opening of the fistula and allowed to continue downward under the skin in the direction that the fistulous tract takes (Plate 407, Fig. 1). The overlying skin, including the polypus, is then dissected off (Plate 407, Fig. 2), and the wound is allowed to heal by granulation.

I. SIMPLE FISTULA IN ANO

Where a fistula in ano is present which has the internal opening low down in the bowel and from which a single tract runs rather superficially through the perirectal tissue and opens two to three inches from the bowel, an excision of that tract is carried out. (Plate 408.)

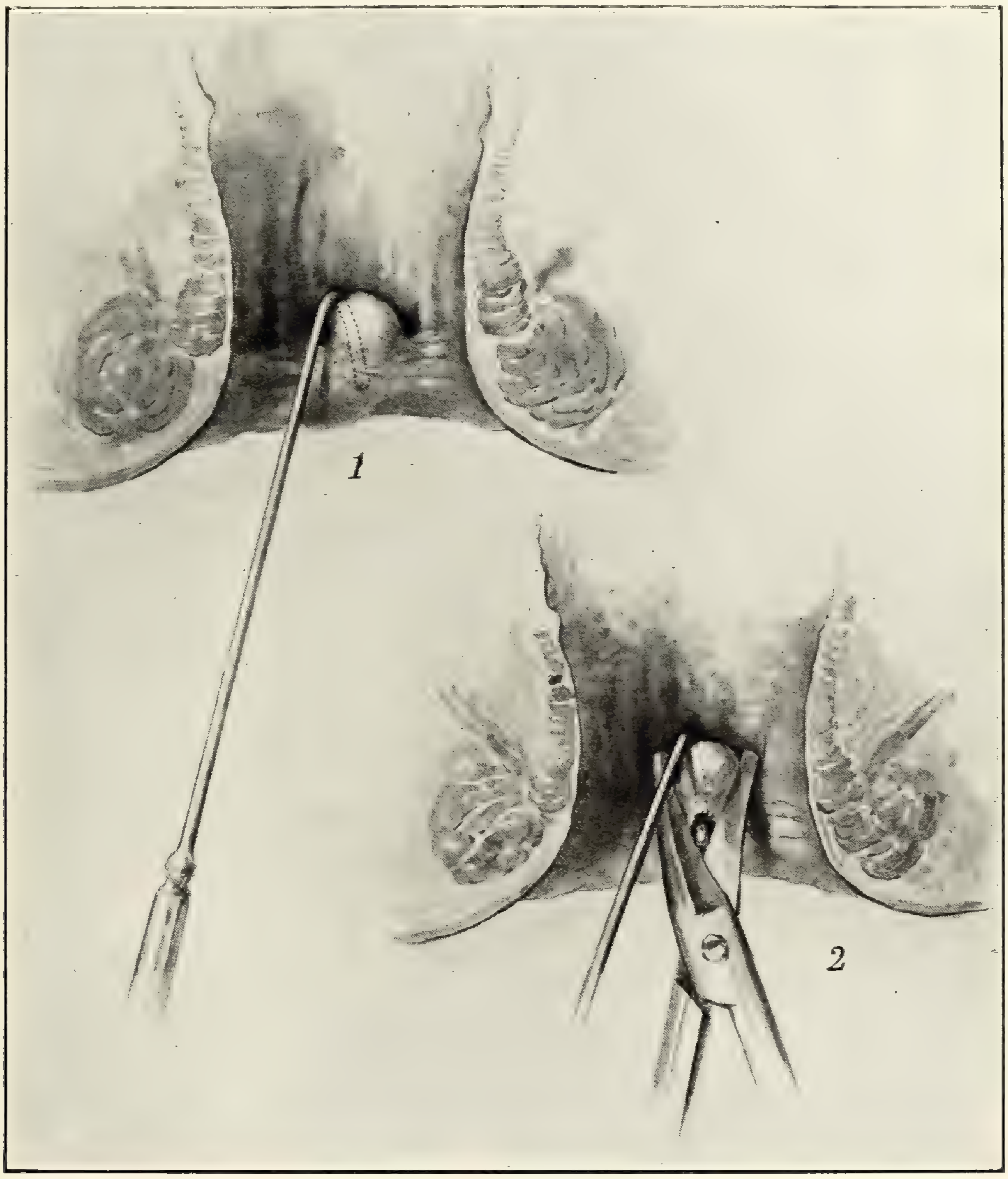

Plate 407. Small Blind Internal Fistula

1. Fishhook probe in internal opening of blind fistula at mucocutaneous line. Hypertrophied polypoid skin overlying it.

2. Excision of skin overlying fistula.

The principle of circular anæsthesia is used in which the operative field is surrounded by ½ per cent novocaine.

Three *intra*dermal wheals are made in the skin (Plate 408, Fig. "1, 2, 3"); one an inch away from the external opening of the fistula and one on each side of the probable course of the fistulous tract. These wheals are then connected by subcutaneous injection of ½ per cent novocaine. Through each of these same wheals a deep injection is carried out in a fan-shaped manner (Plate 408, Fig. 1, "3") which reaches the nerves beneath the fistulous tract. About 40 c.c. of ½ per cent novocaine are used for this whole procedure.

At the conclusion of the injection of the novocaine the field is usually anæsthetic and the fistula can be dissected out. (Plate 408, Fig. 2.) The wound is packed lightly with vaselined iodoform gauze and allowed to heal by granulation from the bottom.

II. FISTULA IN ANO WITH THE FISTULOUS TRACT RUNNING ABOVE THE EXTERNAL SPHINCTER MUSCLE

The local anæsthesia is carried out in the same manner as just described.

The operative treatment may be carried out by excision of the fistulous tract, in which event the external sphincter muscle is divided at right angles to its fibers in a single plane. If this division occurs directly in the posterior commissure, the divided ends of the muscle are splinted to some extent by the fibrous extension of the muscle to the coccyx and, consequently, marked gaping of the cut muscle does not occur. If, however, the external sphincter muscle is completely divided in its lateral aspect, considerable retraction of the denuded ends may occur if, coincidentally, a defect in the soft parts peripheral to it has been made in dissection of fistulous tract. This may result in partial incontinence and is a condition to be avoided. Consequently after excision of the fistulous tract into the rectum (Plate 409, Fig. 1) the sphincter muscle is reconstructed by placing three or four catgut mattress stitches through it, so that no dead space may exist in the deepest portion to reform the fistula. In cases such as these there is also considerable gaping of the soft parts and when the sphincter muscle is reconstructed, interrupted catgut stitches are placed in the deep layer of the superficial fascia which obviate the formation of a pocket under the resutured edges of the sphincter muscle. (Plate 409, Fig. 2.) The skin edges are not sutured and sufficient drainage takes place between stitches to prevent abscess formation in the depth of the wound. This partial reconstruction of the operative field also materially shortens convalescence and effectively prevents partial incontinence of the sphincter muscles.

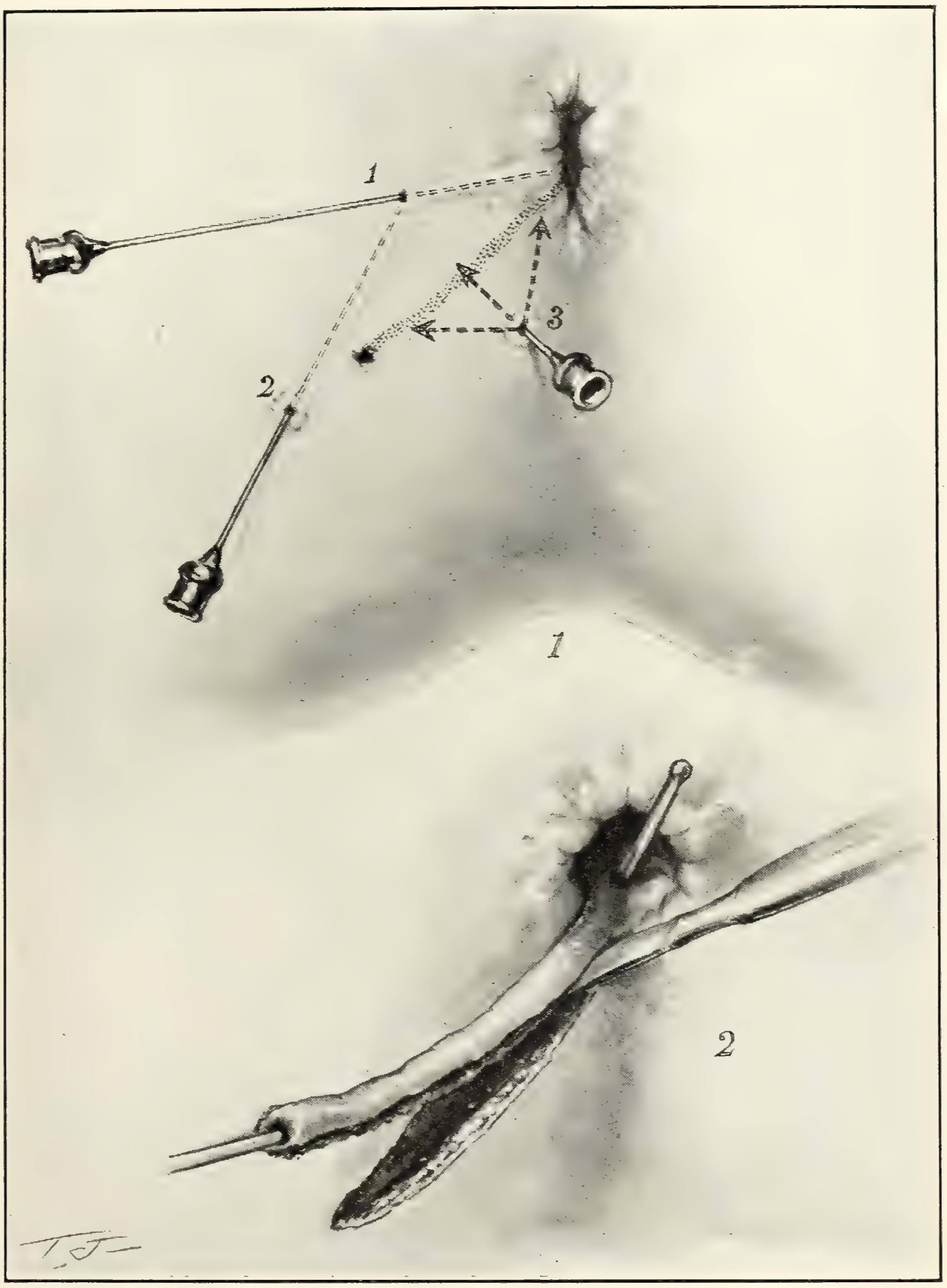

PLATE 408. SIMPLE FISTULA IN ANO

1. Method of local anæsthesia. "1" and "2" show *intra* dermal wheals from which subcutaneous injection of novocaine surrounds the lesion *sup*erficially. "3" shows deep injection in a fan shaped wall which is carried out on both sides of the fistula and surrounds it in the depth.

2. Excision of the fistulous tract including the internal opening.

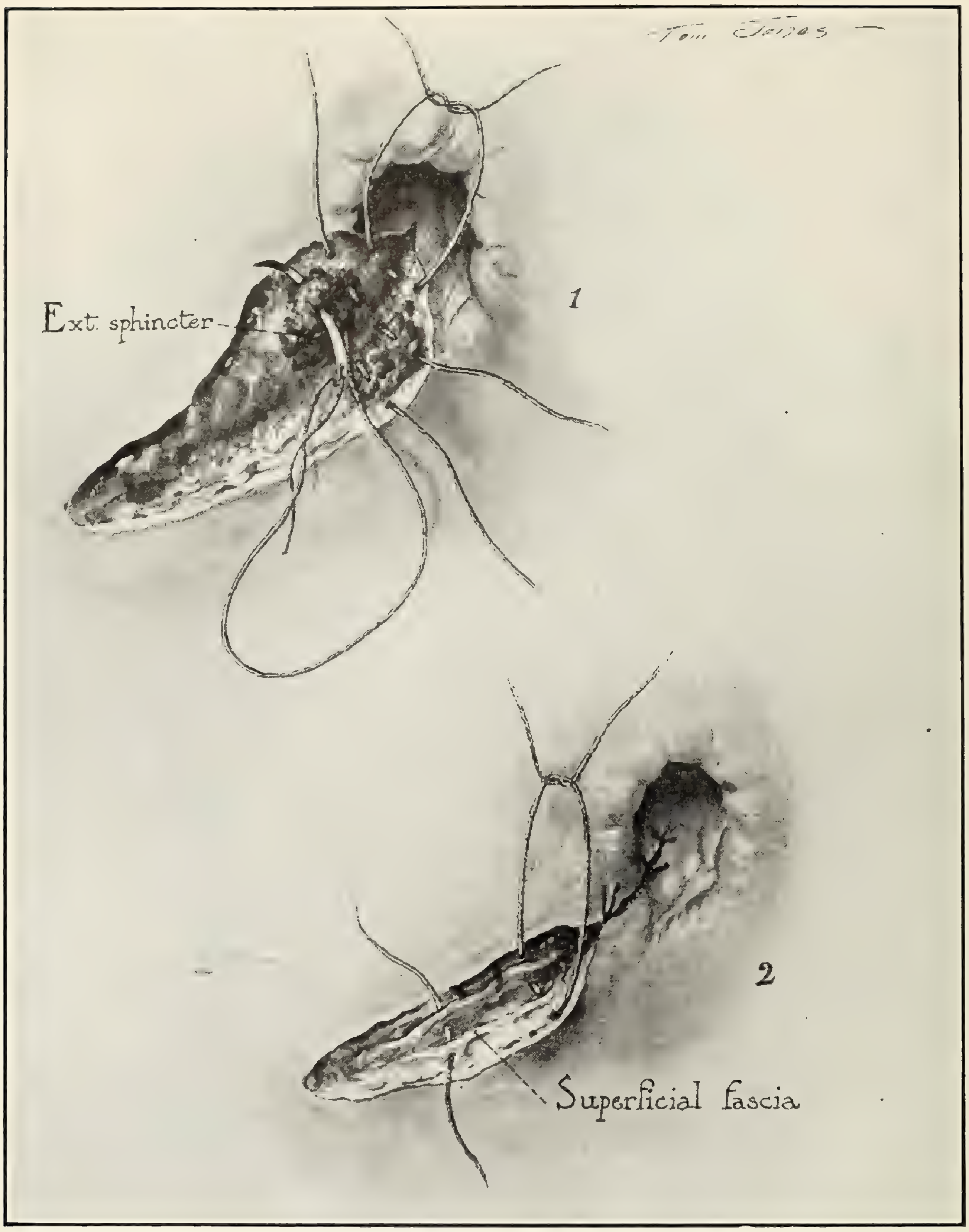

Plate 409.

1. Division of a fistula into the rectum cutting all of the external sphincter muscle. Mattress catgut stitches obliterating dead space and reuniting the cut edges of the external sphincter.

2. Interrupted catgut stitches through the superficial fascia which also obliterate dead space beneath it.

III. Y-SHAPED FISTULA IN ANO

Certain neglected simple fistulæ in ano become complicated by chronic ischiorectal abscesses, owing to improper drainage through the external cutaneous opening of the fistula. On examination of these fistulæ one sinus is found to run into the depth of the ischiorectal fossa and another one toward the rectum. (Plate 410, Fig. 1.) The deep sinus running into the ischiorectal fossa rarely communicates with the bowel, so that in the operative management, the fistulous tract running into the rectum is dissected out as described above and the deep sinus running into the ischiorectal fossa is drained. (Plate 410, Figs. 2 and 3.) This deep sinus will heal when the fistula in ano has healed because reinfection of the ischiorectal region will be obviated. These cases are best treated under general anæsthesia.

IV. HORSE-SHOE FISTULÆ

When from an internal opening of a fistula on the anterior or posterior rectal wall, ischiorectal abscesses develop in both fossæ and are opened or open externally, a fistula results which partially or almost completely encircles the rectum. The lower bowel may also be partially encircled by two separate fistulæ, each with an internal opening of its own. In such event, these fistulæ should be operated upon separately and one should be allowed to heal before the other is operated upon.

In the first instance, where only one internal opening exists, that opening is usually found on the posterior wall. After the fistulous tracts have been surrounded by both superficial and deep injection of ½ per cent novocaine-adrenalin (Plate 411, Fig. 1), it is usually possible to connect the two fistulous tracts posteriorly *outside* of the sphincter ani muscle, and the external sphincter muscle is then divided in the posterior commissure in a single plane (Plate 411, Fig. 2). If the fistulous tracts from either side are connected directly through the external sphincter muscle with the internal opening of the fistula, the muscle is cut in two planes, and it may be considerably weakened (Plate 411, Fig. 2 "A"). This should be avoided if possible, but whenever it is necessary, the sphincter should be reconstructed as has been described (Plate 409).

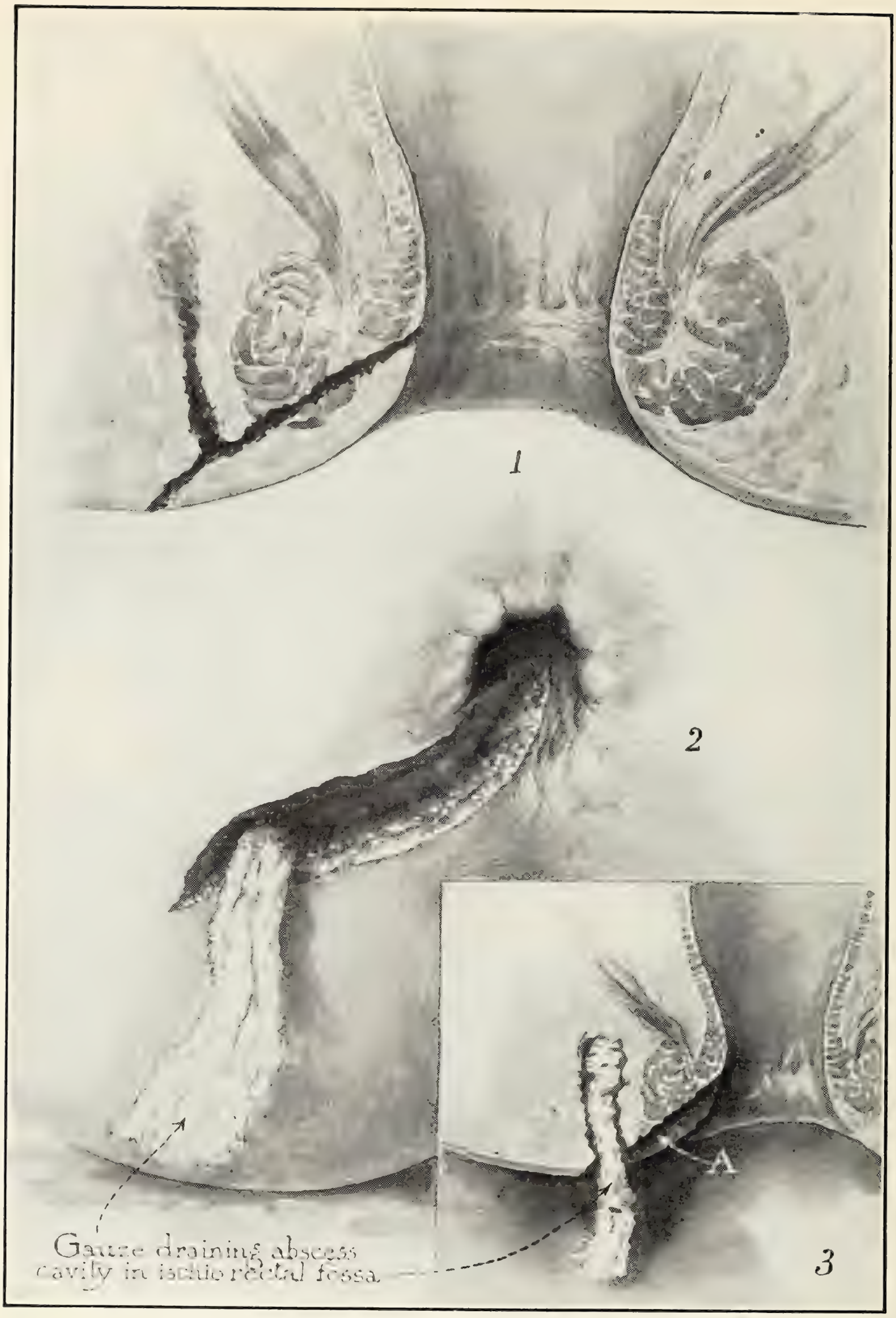

Plate 410. "Y"-Shaped Fistula in Ano

1. Longitudinal section of rectum. Fistulous tract leading into rectum between sphincters and a communicating tract leading to the ischio-rectal fossa at the end of which is an abscess.

2. Division of fistulous tract into rectum and drainage of ischiorectal fossa.

3. Longitudinal section of rectum showing ("A") divided fistulous tract into rectum and drain in ischiorectal fossa.

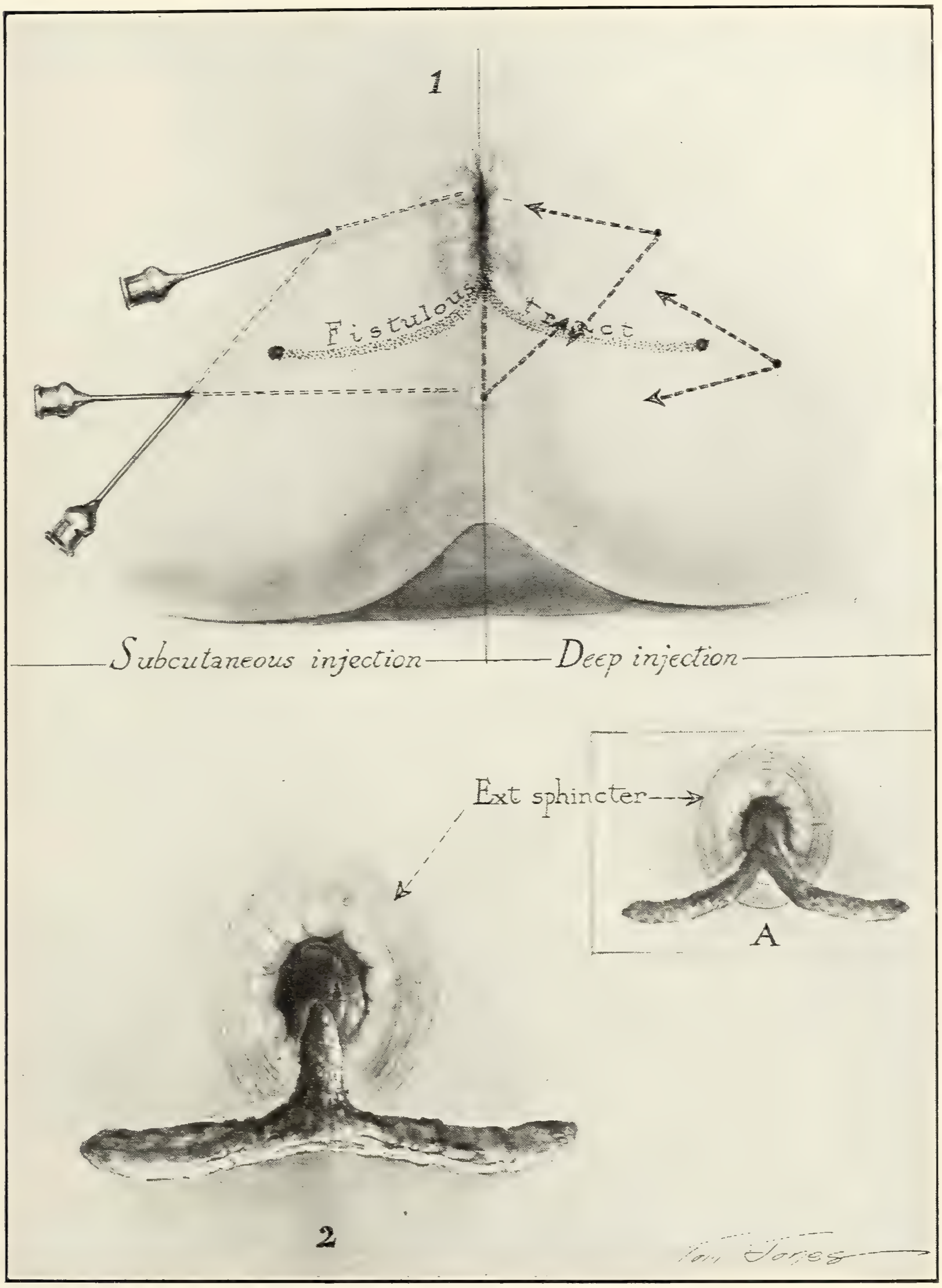

Plate 411. Horseshoe Fistula in Ano with the external openings on right and left buttocks and the internal opening on the posterior wall of the rectum.

1. On left *sub*cutaneous injection of novocaine through *intra* dermal wheals, on right method of deep anæsthesia by fan shaped injection of novocaine.

2. Connection of right and left fistulous tracts outside of sphincter and muscle with single incision through the external sphincter muscle.

2a. *Incorrect* method of connection of two fistulous tracts at internal opening of fistula which necessitates double division of external sphincter muscle.

V. FISTULA IN ANO WITH THE INTERNAL OPENING HIGH IN THE RECTUM

If the internal opening of a fistula in ano lies above the external sphincter ani muscle, a complete severing of the muscle by operation may result in partial or complete incontinence. Reconstruction of the muscle can be accomplished as already described (Plate 409), or the fistula can be cured by obliteration of the internal opening through a plastic operation, the principles of which were described by Elting. Local anæsthesia is used to surround the fistulous tract as well as the lower bowel by a wall of ½ per cent novocaine-adrenalin. The internal opening of the fistula is well exposed by means of a self-retaining bivalve speculum. An elliptical incision is made at the mucocutaneous line, and a flap of mucosa of the bowel, which contains the internal opening of the fistula, is raised from the muscularis of the bowel (Plates 412 and 413). This flap of mucosa is mobilized by blunt dissection for about an inch above the internal opening of the fistula. The mucosa containing the internal opening, as well as that distal to the internal opening, is cut off, and the mobilized mucosa remaining is sutured to the mucocutaneous line (Plate 414). By this procedure, the internal opening of the fistula in the mucosa is disposed of and the fistulous opening in the muscularis of the bowel is covered by a flap of healthy mucosa, effectively cutting off the source of infection from the bowel. The external fistulous tract is now well drained or dissected out to the muscularis of the bowel, and the defect in the soft parts drained. (Plates 413 and 414.) The wound in the soft parts heals promptly as it is no longer subjected to reinfection from the bowel. This operation is also well suited to fistulæ with many ramifying tracts in the ischiorectal fossa having one internal opening.

VI. RECTOVAGINAL FISTULÆ

In certain cases of rectovaginal fistulæ resulting from trauma, from perforation by foreign bodies, or from abscess formation, a fistula develops through a normal or nearly normal perineum, making a fistulous tract an inch or more in length (Plate 415, Figs. 1 and 2).

In fistulæ of this type the rectum may be anæsthetized by circular injection of ½ per cent novocaine-adrenalin, care being taken to inject 15 to 20 c.c. of the anæsthetic into the rectovaginal septum. The vaginal opening of one fistula is then mobilized by making a circular incision around it; and with a probe in the fistula, it can be dissected free as a tube down to the submucosa of the rectum (Plate 416, Fig. 1). The tube of tissue containing the fistulous tract can then be turned inside out by drawing the vaginal end of the fistula through the fistulous tract into the rectum (Plate 416, Fig. 2). A purse string suture then closes the deep part of the vaginal wound (Plate 416, Fig. 2), and the fistulous tract hanging free in the rectum is removed by cautery (Plate 416, Fig. 3). This operation has given very satisfactory results in the cases having a fistulous tract into the rectum through a normally thick perineum.

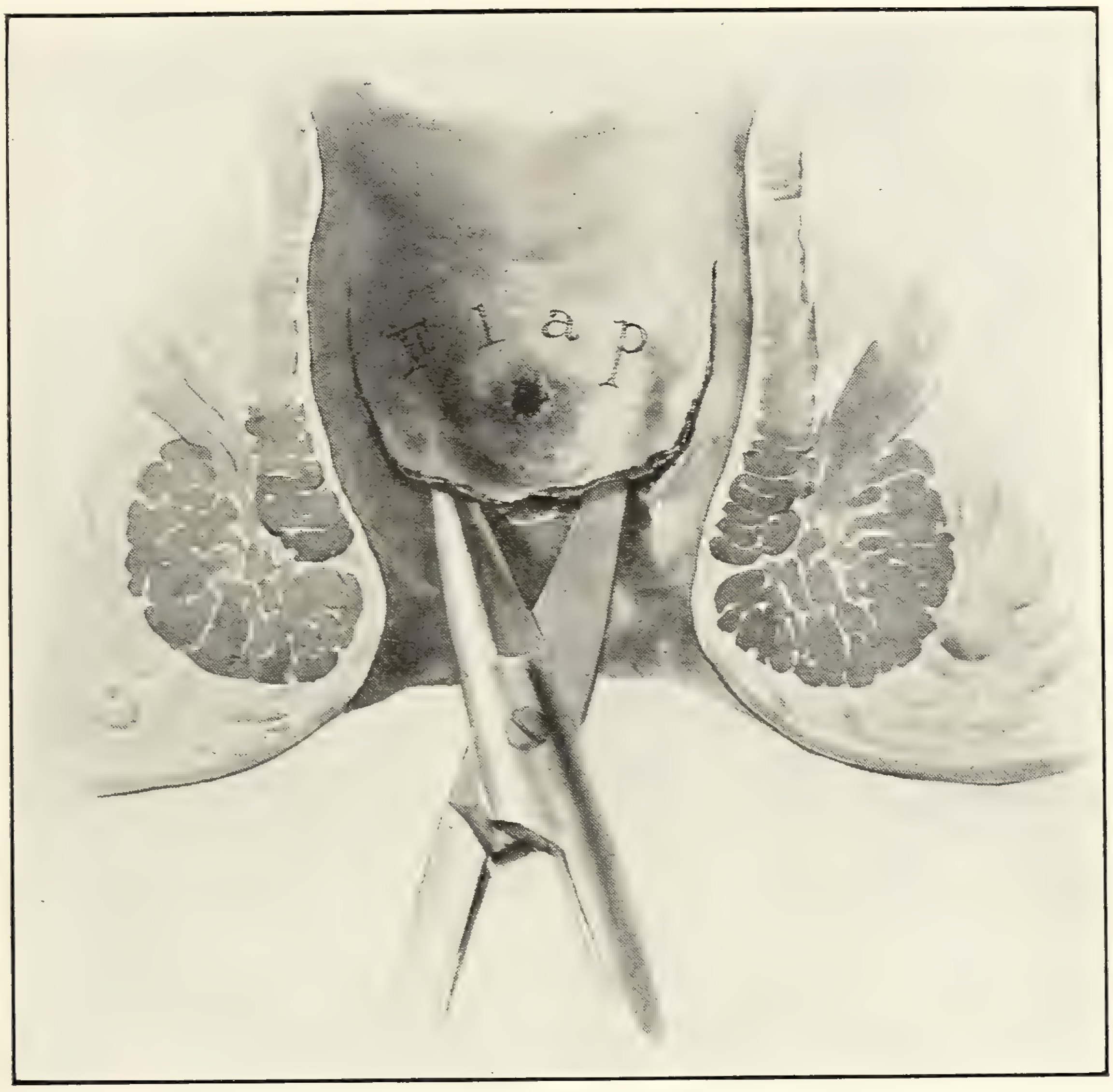

Plate 412. Elting Operation for Fistula in Ano with Internal Opening Above Internal Sphincter Muscle

Longitudinal section of rectum. Flap of mucosa outlined which is dissected free from muscularis and in which is internal opening of the fistula. The internal opening is cut loose from the underlying fistulous tract.

TUBERCULOSIS OF THE ISCHIORECTAL FOSSA. TUBERCULOUS FISTULÆ IN ANO

Tuberculosis of the ischiorectal or perirectal fat very frequently occurs without demonstrable lesions in the rectum. This may mean that the infection is hematogenous or that tubercle bacilli have penetrated the bowel wall to form foci outside of it without making any demonstrable lesion in the bowel wall. This has been experimentally proved

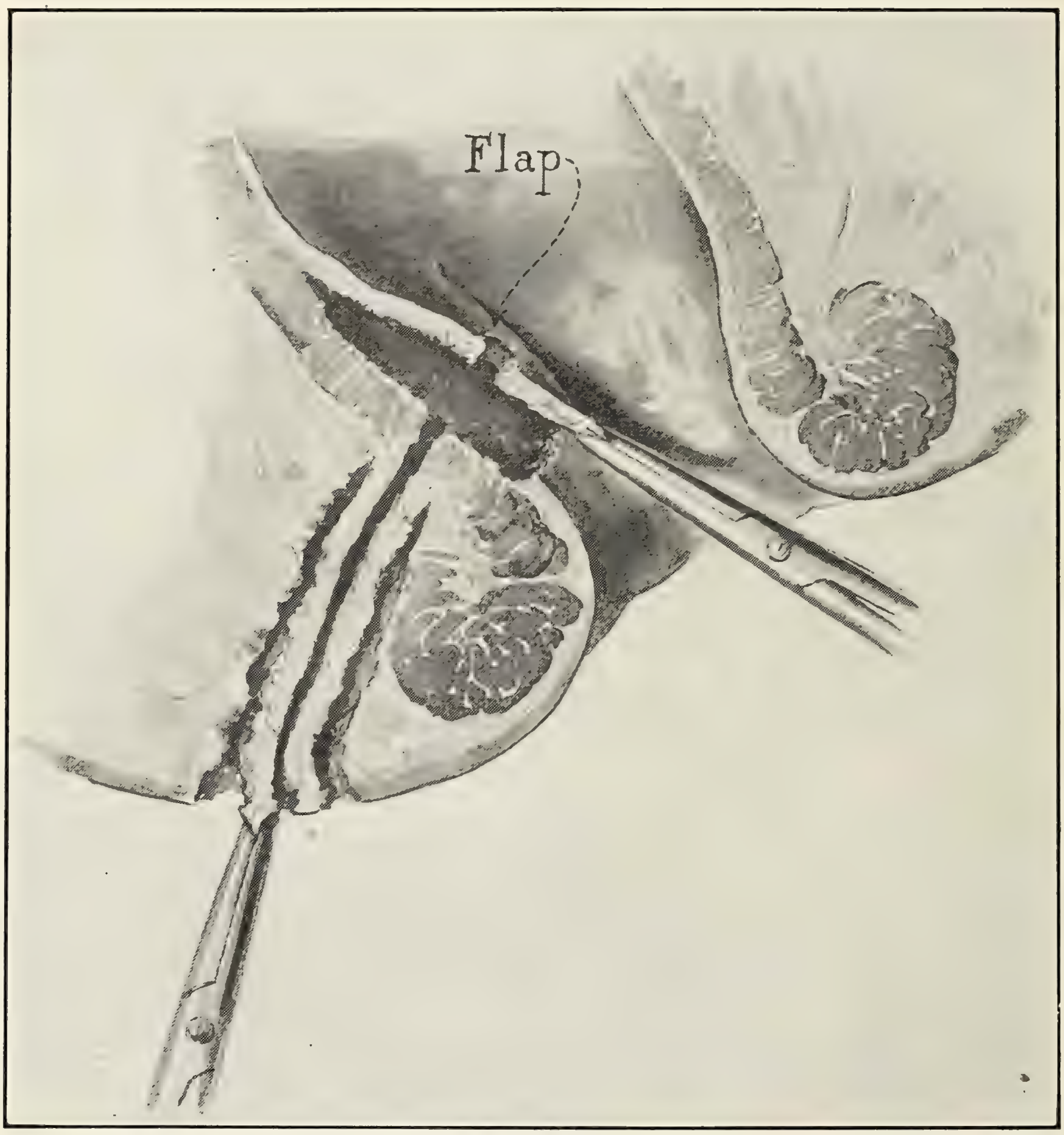

Plate 413. Elting Operation for Fistula in Ano with Internal Opening Above Internal Sphincter Muscle

Longitudinal section of rectum showing fistula in profile with flap of mucosa raised containing internal opening of the fistula.

The fistulous tract is shown dissected out up to the muscularis of the bowel where it is cut off.

to be possible in the small bowel. In some instances where widespread tuberculosis of the large bowel is present, fistulæ develop which undoubtedly have their source in tuberculous ulcers of the rectum. Unless one sees many patients suffering with constitutional tuberculosis, this latter type of tuberculous fistula will be uncommon in his experience.

Tuberculous fistulæ in ano comprise about 20 per cent of the fistulæ seen in private practice and about 40 per cent of those examined in a charity service. In other words, the relative number of tuberculous fistulæ depends to a large extent on the element of personal hygiene and general resistance. Negroes are especially liable to tuberculous fistulæ, in much the same proportion as to generalized tuberculosis.

The development of a tuberculous fistula in ano is usually insidious, beginning outside the bowel in the perirectal or ischiorectal fat as a small painless induration. This indurated area may fluctuate in size, but it

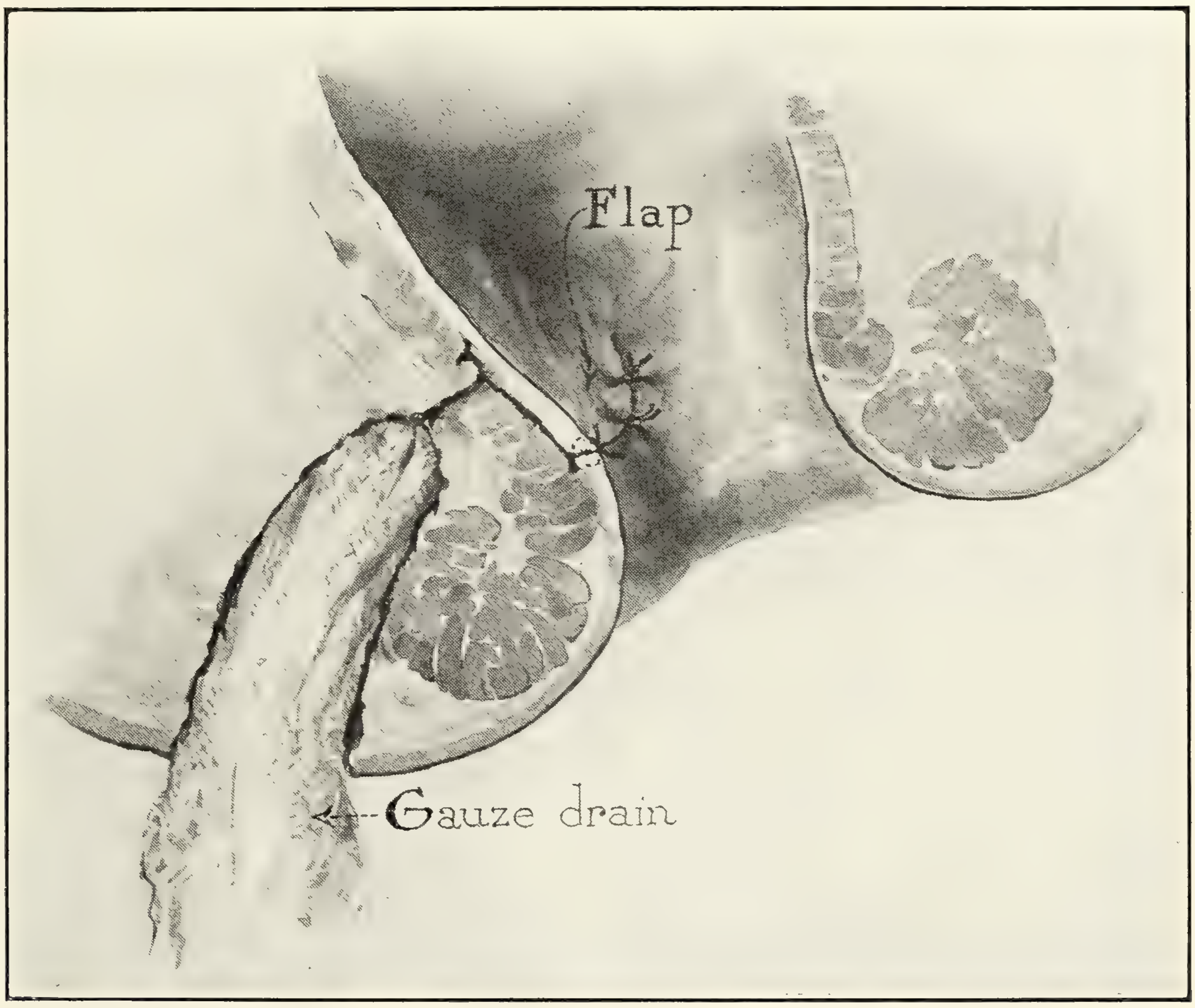

Plate 414. Elting Operation for Fistula in Ano with Internal Opening Above Internal Sphincter Muscle

Completion of operation. Flap of mucosa distal to the internal opening of the fistula has been removed and the remainder of the flap sutured back to the skin effectually covering the site of the fistulous opening into the bowel. The gauze drain fills the defect left from dissection and removal of the external fistulous tract.

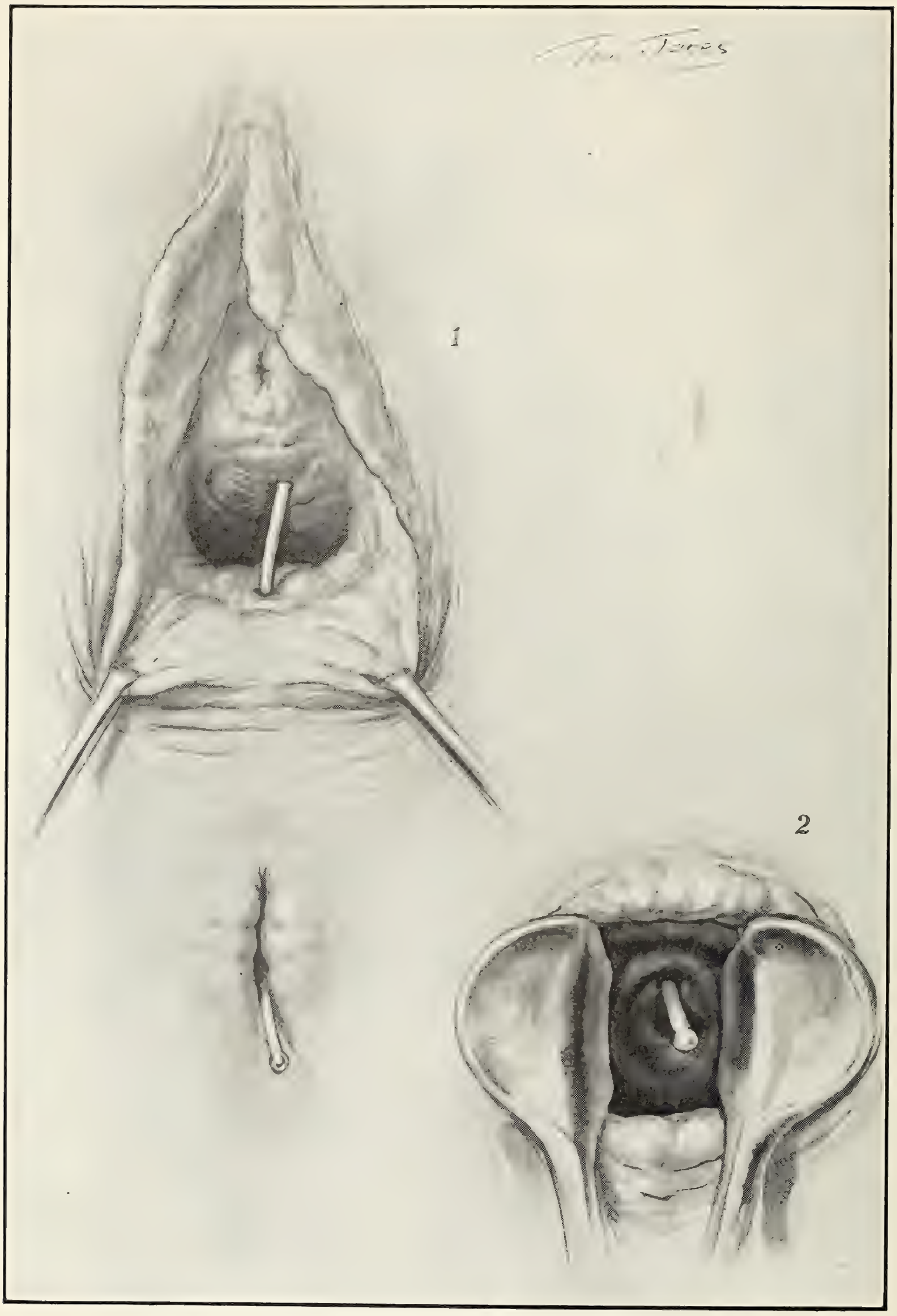

PLATE 415. REPAIR OF RECTOVAGINAL FISTULA

1. Rectovaginal fistula with intact perineum.
2. Rectal opening of fistula above external sphincter.

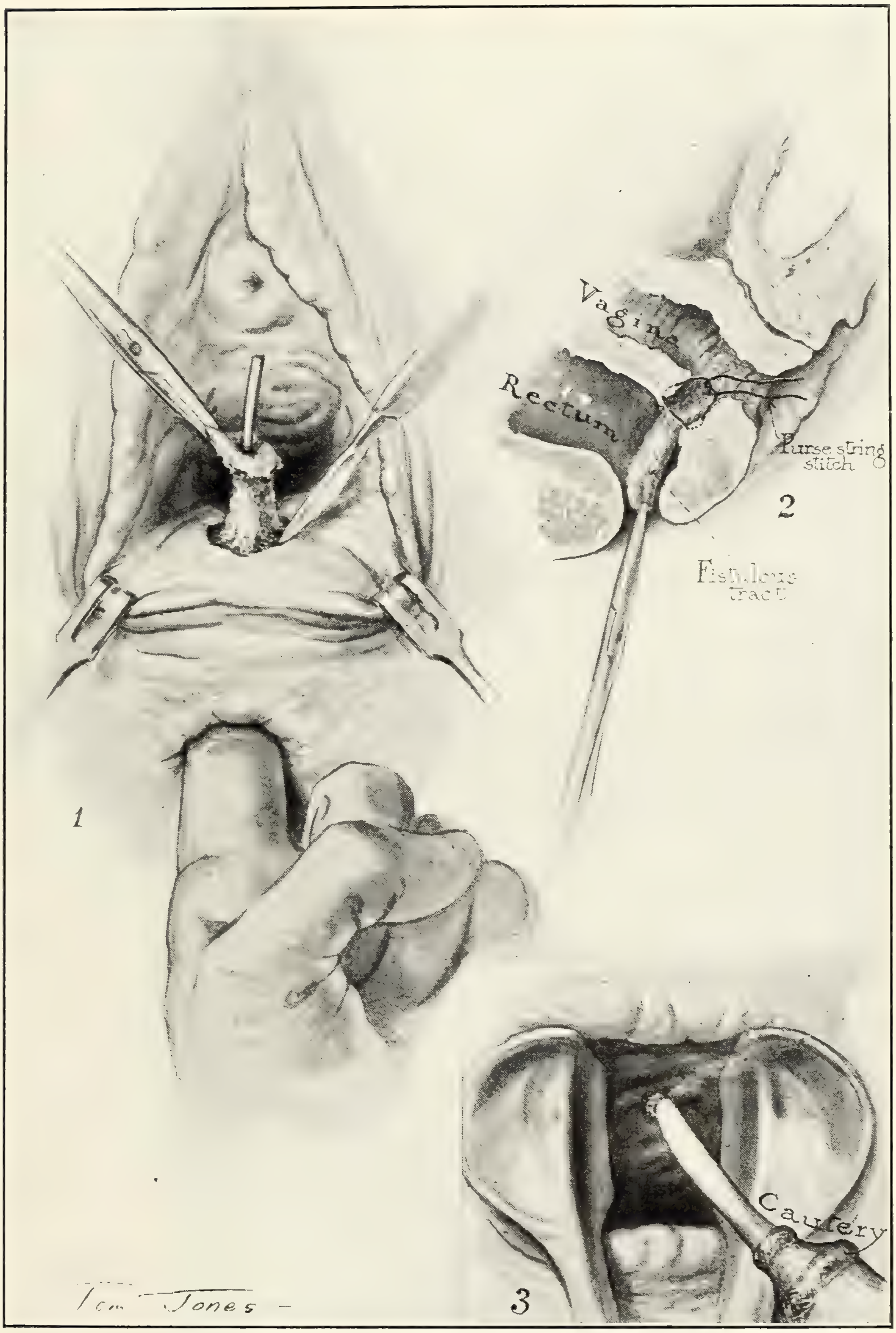

Plate 416. Repair of Rectovaginal Fistula

1. Excision of fistulous tract from vaginal side by sharp dissection down to submucosa of bowel. Finger in rectum as a guide.

2. Inversion of fistulous tract into rectum by turning it inside out, purse-string suture drawing together muscularis of bowel and perirectal tissue.

3. Removal of fistulous tract by cautery through the rectum.

gradually becomes larger and more superficial, so that it is more easily palpated and outlined. Usually it attaches itself to the skin and slowly breaks through the skin or is opened by an incision. A varying amount of thick, grumous pus escapes, consisting of tissue débris, leucocytes, and blood. Cultures are usually sterile, and upon smear tubercle bacilli are rarely found. The onset, therefore, is in strong contrast to that of the pyogenic fistulæ in ano. The size of the lesion may vary from that of a walnut to that of an orange. Uncommonly the whole ischiorectal fossa is involved, with projections upon the scrotum or the vulva.

Involvement of the rectum is usually secondary, resulting from the subcutaneous process ulcerating through into the bowel. This causes one or more openings into the rectum, and these openings are not localized at the mucocutaneous line, but may be above or below it.

Occasionally small masses of the size of a filbert develop under the mucosa of the bowel; and these masses break down, ulcerate into the bowel, and make an external opening through the skin by reason of the formation of a small cold abscess. These small masses have the appearance of perirectal lymph glands which have become infected with tuberculosis.

In other cases small painless fistulous openings develop in the skin around the anus. The skin around these openings is undermined and the sinuses may or may not communicate with the bowel.

In all of these examples of the types of tuberculosis around the lower bowel constitutional symptoms may be absent. When deep induration is present with somewhat extensive involvement of the ischiorectal fossa, anæmia, loss of weight, fever, and sweats may be present.

In the treatment of tuberculosis around the rectum, it is advisable to excise the tuberculous focus entirely before fistula formation with the subsequent secondary infection occurs. This procedure offers the most favorable prognosis. When a large tuberculous abscess has formed, it should be opened and the broken-down material in it gently evacuated. Secondary infection will occur in such an abscess, but eventually the lining of the abscess cavity will contract and the walls become thick; then the whole lesion can be excised up to the point where it is in contact with the bowel. (Plates 417 and 418.)

If the tuberculous process has broken into the bowel low down, the tract can be excised, going into healthy tissue, and the bowel wall reconstructed. If, however, the opening into the bowel is higher or is multiple, the only feasible procedure is to try an Elting method of closure. The prognosis for cure in this type is not very good, for any plastic operation in or around tuberculous material is of doubtful value.

INCONTINENCE OF THE SPHINCTER ANI MUSCLE

Cutting through all of the fibers of the internal sphincter muscle at right angles to their course will result in a very small percentage of incontinence of that muscle, provided the soft parts surrounding the

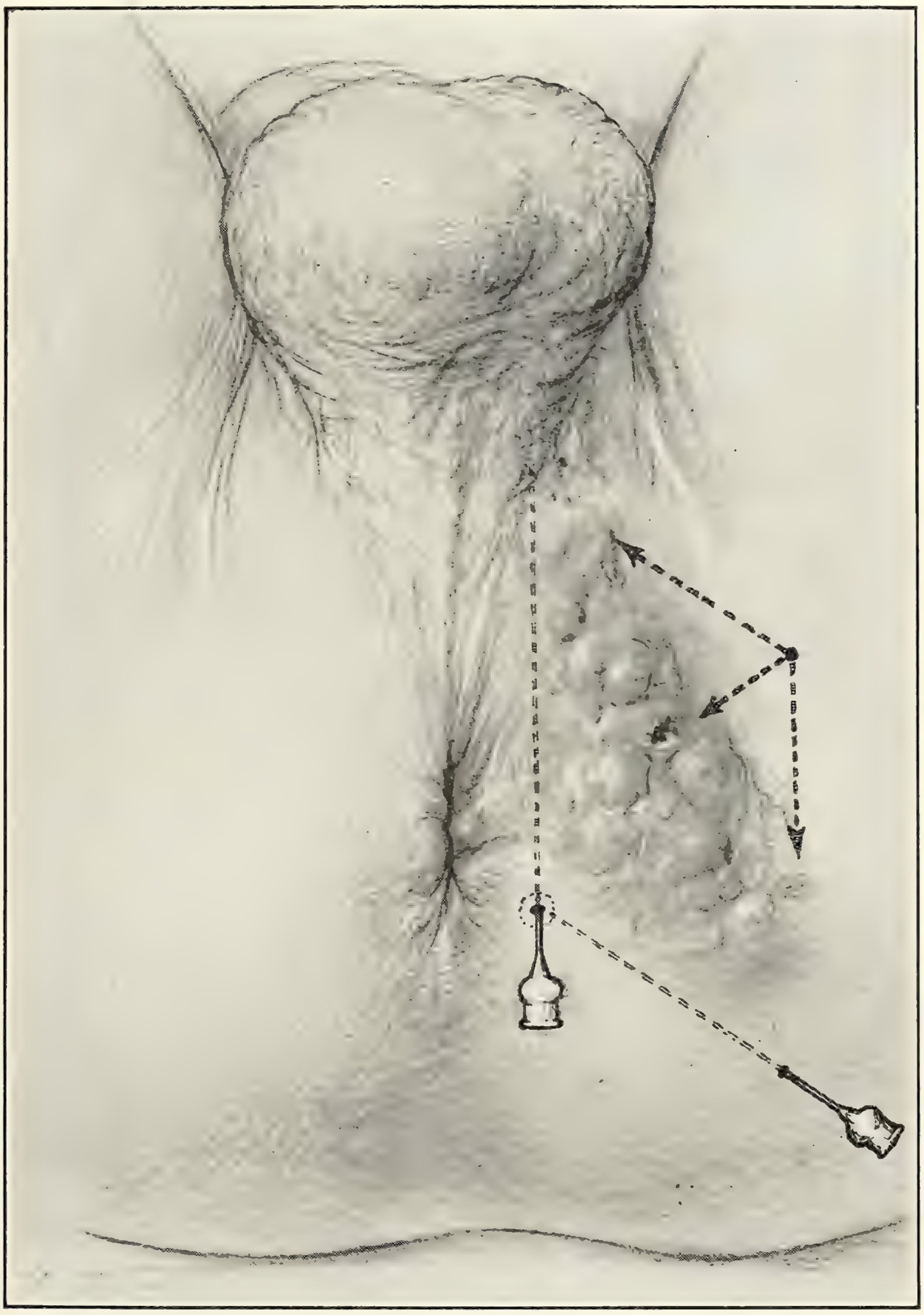

PLATE 417. TUBERCULOSIS OF ISCHIO-RECTAL FOSSA

1. Needles to left show principle of *sub*cutaneous injection of ½ per cent novocaine around the lesion through *intra* dermal wheals.

Arrows on right show principle of fan shape injection into the depth so that the tuberculous lesion is surrounded by a wall of novocaine.

muscle are intact. If, however, a large soft part injury or operative defect accompanies the division of the external sphincter, enough scar tissue will form between the ends of the denuded sphincter muscle to interfere with its perfect function in a considerable number of cases.

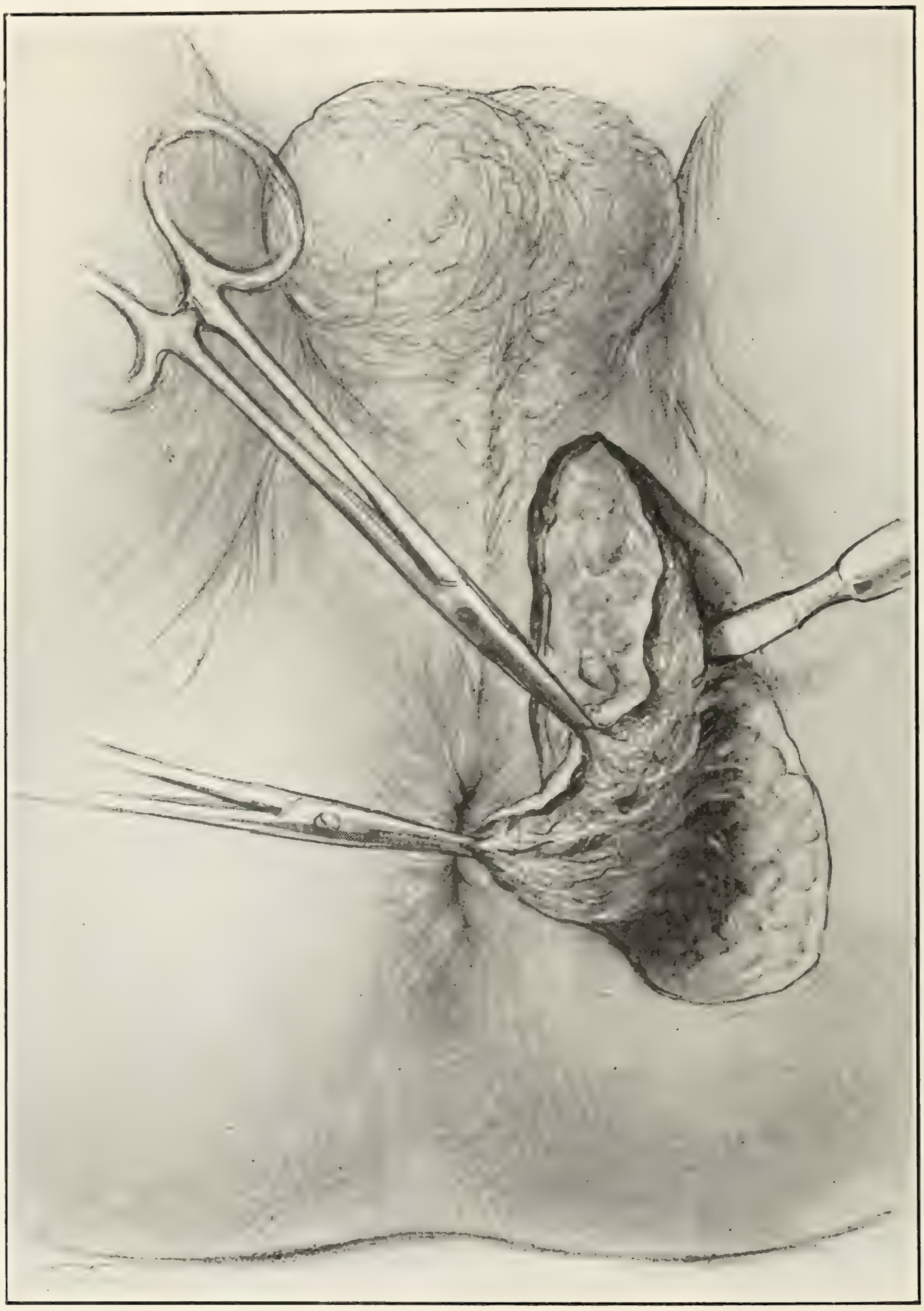

Plate 418. Tuberculosis of Ischio-Rectal Fossa

Block dissection of tuberculous tissue excising the whole lesion through healthy tissue.

This is still more likely if the division of the muscle has been in any other segment than the anterior or posterior commissures. At both these latter sites the muscle is supported by anterior and posterior attachments to the perineal muscles and the coccyx respectively. Tight packing or long continued packing between the denuded ends of the muscle tends to the formation of considerable scar tissue in the muscle. The incontinence may be only for gas, and therefore not so troublesome as when incontinence of feces results.

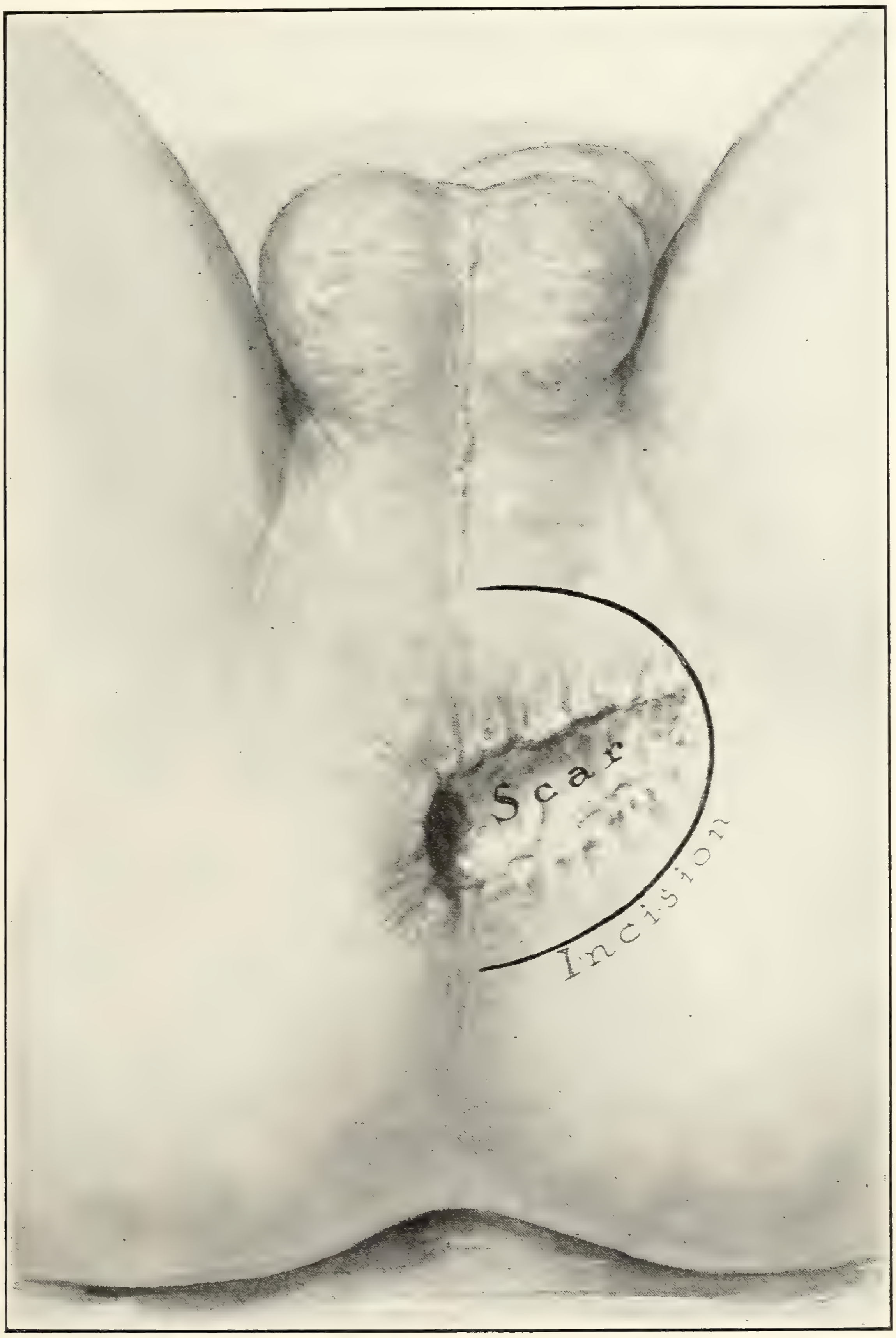

PLATE 419. INCONTINENCE OF SPHINCTER ANI

1. Scar resulting from operation of an extensive fistula in ano which separated the cut ends of the external sphincter and caused an incontinence. Line of incision outlines a flap consisting of skin, superficial fascia and fat.

In operations to restore the continence of the sphincter muscle it is much better to raise a rather large flap of skin and subcutaneous fat by a circular incision at some distance from the rectum. The incision should encircle the scar tissue invading the region of the sphincter muscles (Plate 419). This procedure lends itself well to local anæsthesia. Three or four intradermal wheals are placed well outside the scar tissue in the general line of the proposed incision. These wheals are connected by a subcutaneous injection of ½ per cent novocaine-adrenalin, and following this a deep injection is made under the scar tissue from the several wheals. In addition, a unilateral injection is made outside of the sphincters on the affected side. The flap of skin and subcutaneous fat is then reflected toward the bowel until the denuded ends of the external sphincter muscle appear (Plate 420, Fig. 1). The scar tissue between the muscle fibers is then dissected out so that healthy muscle fibers remain. Usually there are from eight to twelve well defined muscle bundles making up the muscle. These are drawn together by mattress sutures and reinforced by whatever additional catgut sutures are needed after the mattress sutures are tied (Plate 420, Figs. 2 and 3). The flap of skin and subcutaneous tissue is then replaced and sutured back into place. In approaching this region by means of a flap, infection of the sphincter region is avoided, the occurrence of which would defeat the purpose of the operation.

PROLAPSE OF THE RECTUM

The etiology of prolapse of the rectum is not entirely clear. Perhaps the most outstanding fact is its frequent occurrence in infancy and childhood. Napalkow's statistics show that over 60 per cent of the cases were in children between one and three years of age. Waldeyers' post-mortem study of the pelvis in a number of children who had prolapse of the rectum brought out the fact that the anterior concavity of the sacrum was much diminished, with the result that the ampulla of the rectum no longer settled into it on any increase of intra-abdominal pressure, but was pushed downward. Zuckerhandl observed that the cul-de-sac of Douglas was deeper in embryonal life and early infancy, reaching the lower border of the prostate, in contradistinction to its usual position at the level of the seminal vesicles in adult life. This low position of the cul-de-sac has been observed in adults having prolapse of the rectum. In addition to these factors, the marked relaxation of the levator ani, sphincters, and rectoperineal and rectococcygeal muscles, in cases of rectal prolapse, is well known. That any one of these factors is the deciding one in the causation of the condition is doubtful. Jeannel and Verneuils have called attention to the rarity of rectal prolapse after traumatism or destruction of the sphincter ani muscles as, for example, after fistula in ano operations or in perineal lacerations. Lenormant

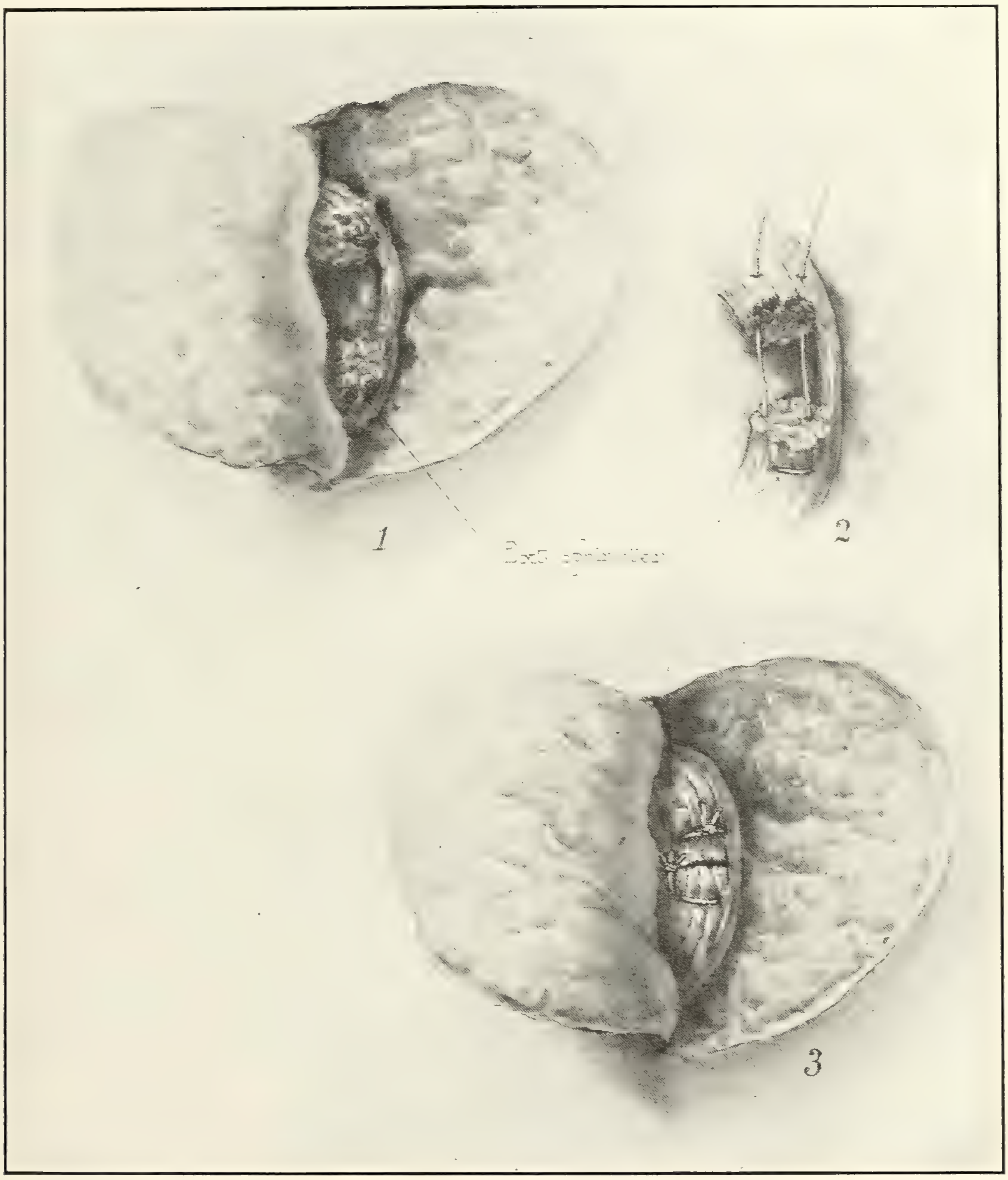

Plate 420. Repair of Incontent External Sphincter Ani

1. Flap outlined in Plate 1 is turned back exposing denuded external sphincter. Scar tissue is dissected out from between the divided ends of the muscle.

2. A mattress suture of catgut is placed in the divided ends of the exposed sphincter and externus which has been mobilized so that when the suture is tied the ends approximate without tension.

3. Suture tied, approximating ends of external sphincter muscle. Another suture tied as an approximating stitch. The flap is then returned to its bed and the skin edge sutured.

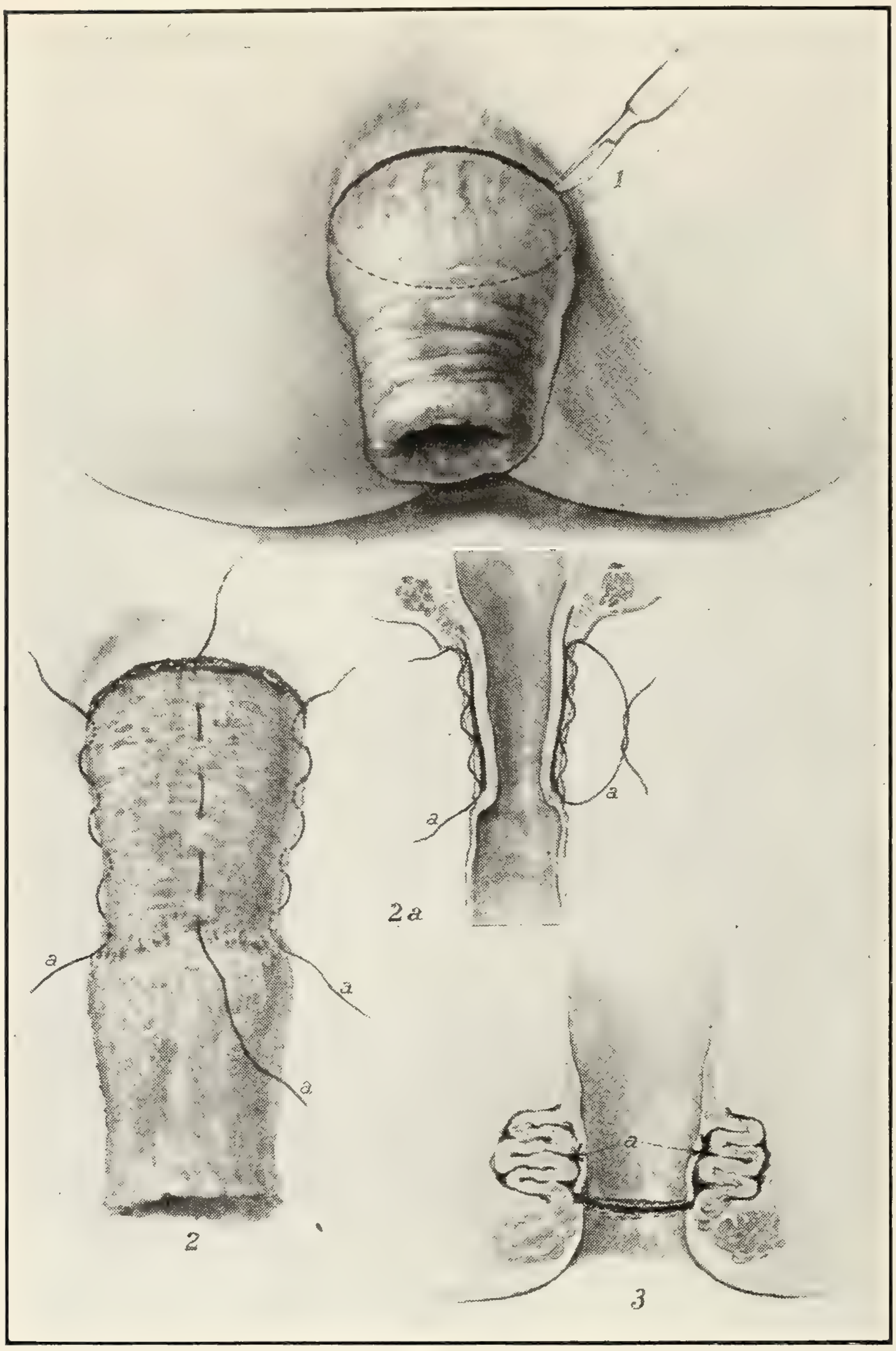

Plate 421. Prolapse of the Rectum. Modified Rehn-Delorme Operation

1. Circular incision at mucocutaneous line from which point the mucosa is dissected loose from the muscularis of the bowel.

2. Mucosa of prolapsed bowel hanging loose at "2." At upper part of picture mucocutaneous line. "A" are sutures catching the muscularis of the prolapsed segment of bowel.

2a. Longitudinal section of drawing 2, showing flap of mucosa dissected free from prolapsed bowel hanging free below. Sutures at "A" catching the muscularis of the outer prolapsed segment. Lumen of prolapsing segment of bowel with intact bowel wall.

3. Sutures "A" tied which reduces the prolapsing segment and puckers the muscularis of the prolapsed segment into a bunch just inside of the external sphincter ani. Enough of the prolapsed mucosa has been removed so that mucosa can be resutured to the skin at the mucocutaneous line without tension.

destroyed the levator ani muscles in dogs and forcibly produced a prolapse of the rectum. This replaced itself and did not recur.

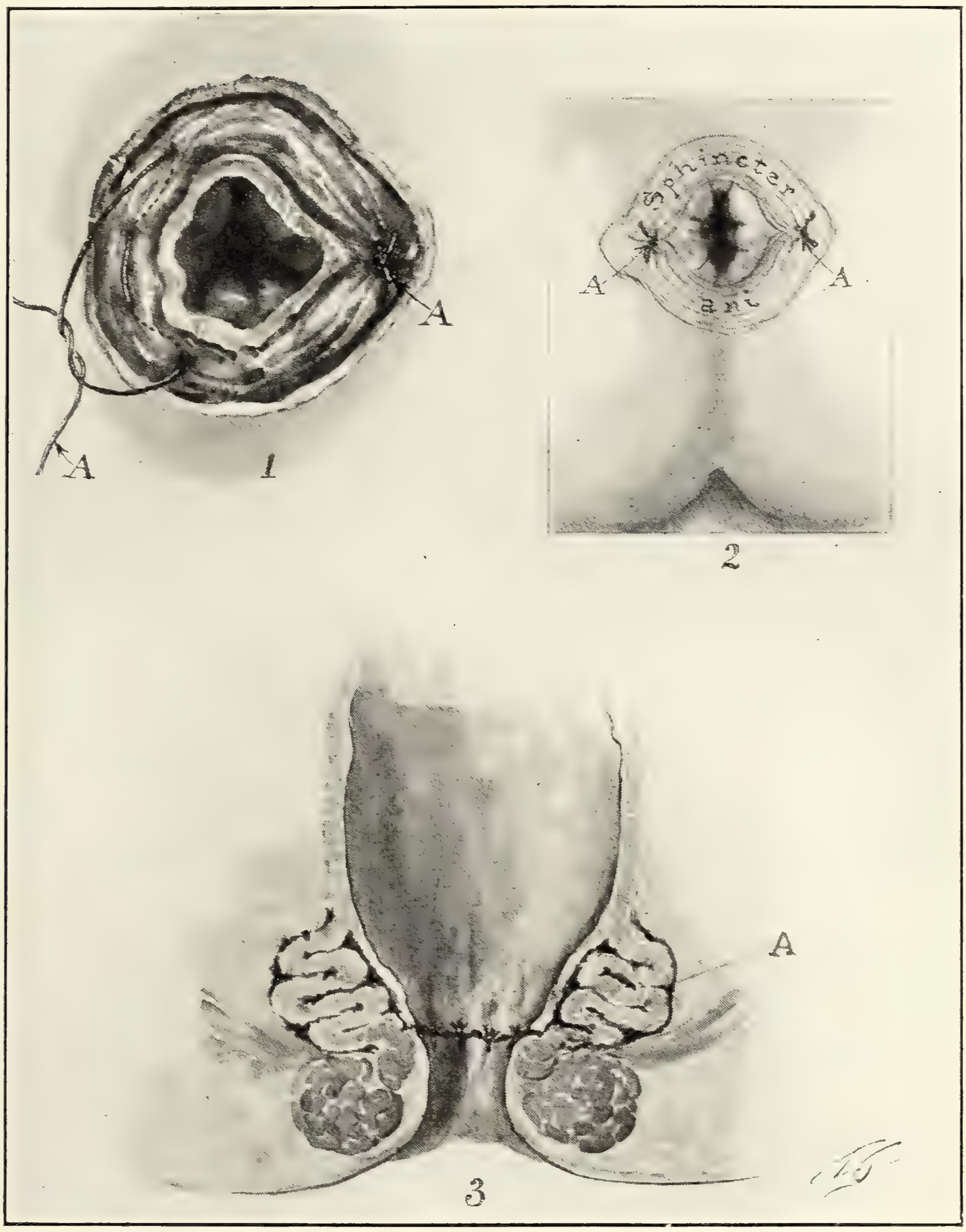

Plate 422. Prolapse of the Rectum

1. Cross section of the rectum at the region of the external sphincter which is in a plane with the incision made at the mucocutaneous line (Plate 402, No. 1). "A" represents catgut mattress sutures which tied lessens materially the circumference of the external sphincter muscle.

2. Sutures tied showing narrowed anal opening by reason of decreasing circumference of external sphincter.

3. Longitudinal section through rectum showing completion of operation with ("A") the muscularis of the previous prolapsed segment of bowel plicated and lying above the sphincter muscle with the cuff of mucosa sutured to the anal skin by interrupted catgut stitches.

As to general factors, it seems to me that prolapse of the rectum is usually seen in individuals whose general muscular tone is weak and atrophic, as in tabes for example. Long standing diarrhœa and factors causing increased intra-abdominal pressure play the principal rôle.

In the treatment of prolapse of the rectum the multiplicity of ways and means stamp the efficacy of the procedures with doubt. Many and varied operations have been proposed. Of them all I regard as the best, the operation described independently by Rehn and Delorme about twenty years ago.

This operation is preferably done under local anæsthesia because the time consumed in the operation and the loss of blood is better tolerated by the patient. A circular anæsthesia of the lower bowel is produced, as has been described, with the exception that the deep injection is carried upward into the levator ani attachment to the rectum. In addition ½ per cent novocaine-adrenalin solution is injected under the mucosa of the prolapsed bowel by inserting the long needles at the mucocutaneous line. This raises the mucosa from the underlying muscularis and makes the dissection of the mucosa from the bowel much easier of accomplishment; it also decreases the amount of oozing during the operation by reason of the adrenalin action on the small blood vessels in the submucosa and muscularis.

A circular incision is made at the mucocutaneous line. The incision goes through the mucosa and completely severs the union of skin and mucosa (Plate 421, Fig. 1). The mucosa is now lifted from the prolapsed segment by blunt scissor dissection, care being taken not to destroy the internal sphincter muscle, which lies directly under the submucosa at the mucocutaneous line. This dissection is tedious, owing to the friability of the mucosa and the tendency to bleeding from the vascular submucosa and muscularis. Hemostasis should be carefully insisted upon. The mucosa is dissected up to the apex of the prolapse, where the prolapsed segment meets the prolapsing segment of bowel (Plate 421, Fig. 2). The denuded muscularis of the prolapsed segment is now divided into four longitudinal segments by the insertion of catgut stitches beginning at the mucocutaneous line, picking up three or four bites of muscularis, and ending at the apex of the prolapse (Plate 421, Fig. 2 "A" and Fig. 2A "a"). When these sutures are tied, the muscularis of the prolapsed bowel is drawn together like a collapsed accordion, and the prolapsing segment of bowel slips back into the pelvis, leaving the longitudinally pleated muscularis lying inside and above the sphincter muscles (Plate 421, Fig. 3 "A").

In most cases of prolapse of the rectum the sphincter muscles are atrophic and incontinent, owing to long continued overstretching by the prolapsed bowel. At this point, therefore, mattress sutures are inserted into one or more quadrants of the external sphincter so that when they are tied the circumference of the external sphincter ani is materially lessened (Plate 422, Figs. 1 and 2). Enough of the mucosa which was dissected from the prolapsed segment is now cut off to allow suture of the mucosa to the skin without tension, and thus the mucocutaneous line is reformed (Plate 422, Fig. 3).

The principles underlying the operation are those of obliteration of the prolapse, pleating of the sphincter ani muscles to restore their continence, and the use of the puckered muscularis of the prolapsed bowel above the sphincter muscles to prevent further prolapse.

GASTROJEJUNAL ULCER

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Gastrojejunal ulcer is a term applied loosely to ulcers occurring at or near the anastomosis of a gastro-enterostomy in the jejunum, usually within 4 to 6 cm. of the stoma, or involving the mucous membrane of the stomach immediately adjacent to the anastomosis. The term gastrojejunal ulcer will be used here for all postoperative ulcers, regardless of location, unless a certain site of ulcer formation is to be specified, when, for instance, the term "jejunal ulcer," will be used, as designating a postoperative ulcer in the jejunum and involving it only. Strictly speaking, a gastrojejunal ulcer is one which forms in relation to the stoma of the gastro-enterostomy and involves jointly the mucous membrane of the stomach and of the jejunum.

The true gastrojejunal ulcer, located at the stoma of a gastro-enterostomy, is reported approximately nine times as often as the postoperative jejunal ulcer. Of 151 gastrojejunal ulcers operated on at the Mayo Clinic, 121 were true gastrojejunal and thirty were jejunal, a ratio of 4 to 1. Gastrojejunal ulcers probably originate entirely within the jejunum, spread secondarily to the stoma and gastric mucous membrane, but rarely, if ever, do they primarily involve the mucous membrane of the stomach. The true gastrojejunal ulcers most commonly involve the mucous membrane to a greater extent on the jejunal side of the stoma than on the gastric. These are true peptic ulcers, both clinically and pathologically, and may be acute, subacute, or chronic.

Gastrojejunal ulcer is one of the most common and distressing postoperative complications. Of 5,607 patients who had gastro-enterostomies performed at the Mayo Clinic for benign ulcer, eighty-three (1.12 per cent) were subsequently operated on for gastrojejunal ulcer. It is probable that this complication developed in other cases of the series and that these patients were operated on elsewhere, or tolerated their symptoms. The incidence of gastrojejunal ulcer has been variously estimated to be from 1 to 10 per cent of all gastro-enterostomies performed. Lewisohn maintains that gastrojejunal ulcers occur in about 4 per cent of gastro-enterostomies, but from 2 to 4 per cent is probably the correct figure. These ulcers are definitely more common after anterior gastro-enterostomy. Moynihan reported ten gastrojejunal ulcers occurring after 633 operations; six after 189 anterior gastro-enterostomies, and four after 444 operations of the posterior type. Gosset reported twenty gastrojejunal ulcers following the anterior, and seven following the posterior type of operation, while Wright collected seventy-two occurring after anterior gastro-enterostomy and only fifty-nine after the posterior type of operation.

Gastrojejunal ulcers are not characterized by definite clinical manifestations, except perhaps by the recurrence of the same symptoms as those complained of prior to operation or of similar symptoms, following a variable period of relief after operation. A more definite clinical characteristic is the change of location and type of pain, with variable food relief or none. Anatomically, the condition is characterized by the appearance of single or multiple ulcers at the margin of the anastomosis, in the jejunum, and possibly in the stomach near the stoma.

Etiology. Gastrojejunal ulcers occur in persons within the ulcer period, that is, from twenty to fifty years of age. According to Eusterman, males predominate in the ratio of 7 to 1, although males are operated on for benign ulcers only three times as often as females. Of the 151 gastrojejunal ulcers reported by us, 136 were in males and fifteen in females.

The cause of gastrojejunal ulcers has been a subject of much speculation, and as yet no one factor can be assigned definitely as the causative agent. Inasmuch as preoperative ulcers occur usually in the duodenum, at the pylorus, or at the lesser curvature of the stomach, and the gastrojejunal ulcers at the site of operation, or near it, there must be some differences in the etiology of the two. In order of frequency, postoperative ulcers occur in the line of anastomosis, usually at the cardiac angle, in the jejunum near the stoma, and rarely in the stomach immediately adjacent to the anastomosis.

Gastro-enterostomy causes a marked change in the physiology of the jejunum. The jejunum is a structure normally accustomed to an alkaline, or a very slightly acid medium. The gastric contents, emptying directly into the jejunum after a gastro-enterostomy, produce a strongly acid environment. Bolton contends that hydrochloric acid above normal in strength can act as a protoplasmic poison to the gastric cells, and may produce a certain amount of devitalizing action leading to autolysis or assisting in it. If this is true of the stomach, the cells of which are accustomed to an acid medium, it would probably be true of the jejunum, where the cells are accustomed to an alkaline, or very slightly acid environment.

Horsley believes that the maximal benefits from gastro-enterostomy are obtained in cases of pyloric obstruction. Eiselberg does not agree with this, as he found four gastrojejunal ulcers following 344 simple gastro-enterostomies, and three following thirty-six gastro-enterostomies in which artificial closures of the pylorus had been performed at the same time. Horsley contends that in these cases of pyloric obstruction the alkaline bile and the pancreatic and duodenal juices are delivered in full strength and amount at the anastomosis, in this way protecting the mucous membrane of the jejunum by neutralizing the acidity of the gastric content. It is obvious that some time would be required to neutralize the acid gastric content in the jejunum, and that the part of the jejunum immediately adjacent to the stoma would be strongly acid, while alkalinity would gradually increase with the distance from the stoma. The portion of the jejunum contiguous to the stoma of the gastro-enterostomy, therefore, is subjected to the greatest acidity, and it is at this site that gastrojejunal ulcers most commonly occur. Gastrojejunal ulcers are comparatively rare in the afferent limb of the jejunum, where the normal alkaline reaction is constantly maintained, but are common following gastro-enterostomy for duodenal ulcers, in which cases the acids are higher than following gastro-enterostomy for gastric ulcers with lower acidity. Furthermore, postoperative ulcers are conspicuously absent in pyloroplasties, resections, and gastro-enterostomies for cancer of the stomach, where the acids are low. Terry reported a case of jejunal ulcer following a gastro-enterostomy for cancer of the stomach, and a jejunal ulcer following resection for carcinoma of the stomach is reported from the Mayo Clinic.

Alterations in the secretion of the stomach, hyperacidity, hypersecretion, or both, cause a relative deficiency of bile, and of pancreatic and duodenal juices, making neutralization of the gastric content in the jejunum impossible. Crohn and Reiss have found that hypersecretion is more often associated with hyperacidity than otherwise, but it is found in all degrees of gastric acidity, even in achylia gastrica. The condition is more common in males, and occurs in from 10 to 15 per cent of all persons with gastric complaints, which agrees more or less with the findings in patients with gastric or duodenal ulcers. Crohn and Reiss maintain that hypersecretion is continuous in a large percentage of cases, and when severe and associated with epigastric pain and vomiting, it is usually due to the gastric or duodenal ulcer. This same deficiency of bile, and of pancreatic and duodenal juices, exists even with normal acidity of the gastric content, if there is a decreased flow of these alkaline juices, or if there has been a diversion of these fluids, as in the Y or Roux operation, when a portion of the jejunum is exposed to the acid of the gastric contents unmixed with these alkaline juices. It is contended that the mucous membrane of the jejunum is more susceptible to the action of hydrochloric acid as the gut is descended, and therefore, that the further down on the jejunum a gastrojejunostomy is made, the more liable is the jejunum to ulcer formation. By various operative methods of diverting the bile and the pancreatic and duodenal juices from the jejunum, Mann has succeeded in producing typical subacute and chronic ulcers in fourteen of sixteen dogs. These ulcers are pathologically almost identical with the peptic ulcers in man, and run a similar clinical course. From these experiments it would seem that the acidity in the jejunum is of prime importance in the production of postoperative ulcers.

It is still a debatable question whether the altered physiology of the jejunum alone produces gastrojejunal ulcers. The use of nonabsorbable suture material, silk or linen, is much discussed as an etiologic factor. Nonabsorbable suture material was found in nine of eighty-three cases of gastrojejunal ulcers in which operation has been performed primarily at the Mayo Clinic, and in eighteen of sixty-eight cases in which the primary operation had been performed elsewhere. Soresi reported a case of gastro-enterostomy for duodenal ulcer, in which the former symptoms recurred four months after operation. At the secondary operation, performed one hundred forty-eight days after the primary, a small ulceration of the mucous membrane of the stomach and another of the jejunum were found, and silk sutures were still in place. The sutures were removed, and twenty months later there had been no recurrence of symptoms. Woolsey reported the case of a patient who had symptoms of a gastrojejunal ulcer, and at the second operation a loop of silk was found hanging free from the edge of the anastomosis, but there was no sign of ulceration. The removal of this thread gave the patient complete relief.

In a series of experiments on animals, using silk or linen in performing gastro-enterostomies, Soresi found suture material hanging within the stoma in forty-six of forty-seven dogs at periods ranging from one to eight months after operation. In three instances definite ulcerations were demonstrated. In another series of experiments on fourteen dogs, side-to-side intestinal anastomoses were performed, with the same kind of suture material. From three to ten months after the operation, thread was found along the line of anastomosis in only two instances and no ulcerations were found. In three of the remaining twelve dogs, calculi were found around sutures, in one instance the calculus being half the size of the lumen of the gut. Recently, at the Mayo Clinic, a catgut knot was found incorporated in a cystic inflammatory mass in the suture line two years after operation.

It is probable that the use of nonabsorbable suture material is of some etiologic importance in the production of a certain number of postoperative ulcers, but not in all.

Roeder believed that errors in technic while performing gastro-enterostomies, with resulting scar formation, are etiologic factors in producing gastrojejunal ulcers. The application of apposing clamps to the jejunum and stomach tight enough to produce hæmostasis and to prevent soiling, is certain to cause some degree of trauma to the mucous membrane of those structures at the site where gastrojejunal ulcers most commonly occur. The strangulation and trauma of tissues by these clamps, and the decrease of blood supply by the use of the usual through-and-through method of suturing, produce a condition suitable for ulcer and scar formation. Cicatricial tissue is less resistant to the action of hydrochloric acid than the normal mucous membrane of the gut. Such scar formation fixes the mucous membrane to the underlying structures, a condition diametrically opposed to its normal mobility over the seromuscular coat. The picture, then, is of an immobilized, thinned, scar-bound mucosa in a region subjected to the maximal mechanical, chemical, and thermal trauma of food passing through the stoma from the stomach into the jejunum. The use of nonabsorbable suture material, obviously a foreign body, produces irritation, which, with the less resistant scar formation, forms a fertile soil for ulcer production. Roeder believes that the minimal trauma and alteration of the blood supply is the best method of preventing the formation of the very undesirable cicatricial tissue. He emphasizes particularly the accurate approximation of the mucous membrane while performing a gastro-enterostomy, and says that in this manner scar formation is largely prevented.

Montgomery has caused typical gastrojejunal ulcers to occur in a series of experiments on animals by producing hæmatomas by pricking blood vessels near the line of anastomosis when performing gastro-enterostomy. However, the ulcers thus formed are found to affect the mucous membrane of the jejunum only at the cardiac angle of the stoma, where suturing and hæmostasis are imperfect. Hæmatomas produced elsewhere along the line of anastomosis are readily absorbed without ulceration; the type of suture material used seems to be of no importance.

Operative errors, like faulty placing of the stoma in such a way as to cause angulation which prevents free drainage, will result in the prolonged presence of gastric content in that part of the gut, thus forming an environment ideal for ulcer formation. A stoma too large or too small, and a loop too long, are also errors conducive to the formation of gastrojejunal ulcers.

Infective processes in various parts of the body have long been held to be causative factors in the production of ulcers. It has been said repeatedly that the cause of the original ulcer is the cause of the postoperative ulcer. Eusterman says that in cases of ulcers seen at the Mayo Clinic, "Extensive dental repair, severe pyorrhea, or dental caries was the rule rather than the exception." It is a well-established fact that ulcers are commonly associated with pathologic conditions of the gallbladder, pancreas, appendix, and other organs. Rosenow believes that hæmatogenous infections with streptococcus from these foci are the exciting factors in the production of ulcers. Reeves has studied the anatomic relationship of ulcers to the arterial vessels which come from the main gastric arteries as they pierce the wall of the stomach. He seems to have shown that the arteries of the lesser curvature of the stomach and of the duodenum are especially predisposed to thrombosis and emboli. If this is true, it is an excellent support of Rosenow's contention. Horsley believes that at the time of the origin of an ulcer the hæmatogenous infection produces an irritation or inflammation of the gallbladder, appendix, pancreas, kidneys, and other organs, and that the ulcer is merely a survival of multiple lesions. If this is so, gastric and duodenal ulcers, as well as postoperative gastrojejunal and jejunal ulcers, are local manifestations of a general systemic condition, and the result of a continual intake of toxins from some point or points of infection. This view is supported by the associated abdominal lesions found in many cases of demonstrable gastric or duodenal ulcer. The clinical seasonable relationship of exacerbations of symptoms in patients with ulcer and in patients following exposure, thus decreasing the general resistance of the body, supports this theory. It is possible that the altered physiology of the jejunum after gastro-enterostomy produces an area of decreased local resistance where hæmatogenous infection could easily be implanted. It has been noted repeatedly that certain persons have an idiosyncrasy to ulcer formation without apparent cause. Whether or not these persons, in whom multiple foci of infection can be demonstrated, belong to the group known as "ulcer bearers", is a matter of conjecture.

Besides the trauma produced at the time of operation, the injuries caused by insufficient mastication, the ingestion of indigestible foods, and excesses in the use of alcohol and tobacco must be mentioned. The anastomosis of a gastro-enterostomy is subject to a healing ulceration for a variable period after operation, and it is entirely plausible that errors in diet, especially soon after operation, would produce sufficient local trauma to cause an ulcer, or at least a persistence of the healing ulceration along the line of suture. Other etiologic factors have been mentioned, such as syphilis, dysentery, and typhoid, but there is little or no evidence to support these arguments. No one factor can be assigned as the cause for gastrojejunal ulcer. It is probably a combination of several factors, chief of which seems to be the alteration of the physiology of the jejunum.

Pathology. Gastrojejunal ulcers occur at or near the site of the previous operation. Of 151 cases of gastrojejunal ulcers following gastro-enterostomy performed at the Mayo Clinic from January, 1912, to April, 1923, 121 were situated at the stoma, and thirty below the stoma, usually from 4 to 6 cm. from the line of anastomosis. Of the twenty-one cases of gastrojejunal ulcers reported by Lewisohn, eighteen were true gastrojejunal ulcers, and three jejunal. Seventeen of the patients were males. One patient had had three operations for recurring gastrojejunal ulcers.

Gastrojejunal ulcers are usually single, but may be multiple, and are usually of the indurative or perforative type. There may be a single jejunal or gastrojejunal ulcer with a contact or "kissing" ulcer on the opposite wall of the gut, or slightly distal to the original postoperative gastrojejunal ulcer. In size these postoperative ulcers range from 0.1 to 2.0 cm. in diameter, the largest dimension usually being in the transverse diameter of the intestine. There may be considerable surface extent, especially in the true gastrojejunal ulcer, involving, as a rule, a larger area on the jejunal than on the gastric side of the stoma. The chronic ulcers are hard, with rigid walls, and with definite local inflammatory reaction. They may be more or less "punched out," with overhanging ulcer edges. The cut surface may be soft and edematous, especially in the acute type of ulcer, or hard, with marked connective-tissue proliferation and round-cell infiltration in the degree of its chronicity. The simple ulcerations usually involve the entire thickness of the mucous membrane of the gut and the remainder of the gut wall, depending on the perforative nature of the ulcer. The associated pathologic conditions obviously would be governed by the acuteness or chronicity, as well as the perforative tendency of the ulcerative lesion. In large chronic ulcers with much local tissue reaction, and in perforative ulcers, there may be exuberant scar formation, which may produce a partial or complete stricture of the bowel.

There are three quite distinct types of gastrojejunal ulcer: Simple ulcer without symptoms, which heals readily; simple ulcer causing definite local and general symptoms; and ulcer definitely perforative in character, which, because of this tendency, produces chronic adhesive peritonitis. This type of ulcer, when the perforation into the colon is complete, forms a gastrocolic or a jejunal colic fistula with the associated pathologic conditions. Perforations may occur into the pancreas, colon, or any neighboring structure, and, owing to obvious anatomic relations, are more common after posterior gastro-enterostomies. There are indications that the majority of gastrojejunal ulcers, and especially of jejunal ulcers, whatever the cause, tend to be perforative in nature. Of 151 gastrojejunal ulcers operated on at the Mayo Clinic, forty-three were definitely perforative, seventy-two were described as indurative, ten as simple, and twenty-six were not classified.

Richardson collected twelve cases of primary jejunal ulcer, seven of which showed evidences of chronicity; ten had perforated, three caused definite stricture of the bowel, and two appeared to be acute. One of these cases was associated with a duodenal ulcer, and another with a gastric ulcer. Three of the twelve were similar in appearance to gastric ulcers, two were described as being definitely "punched out," and one was definitely annular. Sudden perforation without previous symptoms occurred in six, three of which were associated with some type of external violence. One case of perforation followed definitely localized peritonitis. In four cases there had been previous symptoms suggestive of gastric or duodenal ulcer, and in two of these, definite duodenal lesions existed.

Postoperative and primary jejunal ulcers are very similar in their gross appearance. Unfortunately, many of the primary jejunal ulcers reported by Richardson had not been studied microscopically. Bryan reported a case of primary perforated jejunal ulcer without previous gastro-enterostomy and mentioned three others reported by Van Roojen. Parker reported a case with two pyloric ulcers for which he had performed pyloroplasty and gastro-enterostomy in 1901. After three years of complete relief the patient died two days after the perforation of an acute jejunal ulcer. The majority of these reported primary jejunal ulcers were perforative in type, a fact which seems to support Keen's assertion that all jejunal ulcers are perforative.

Wilensky says that for every case of actual gastrojejunal ulceration there certainly are other cases of hyperæmia, irritation, and inflammation, which do not come to operation, and which in some instances disappear spontaneously. This is probably true, since definite areas of duodenitis have been seen repeatedly at operation in patients who have presented definite ulcer symptoms, and in whom no definite ulceration could be demonstrated. As a rule, this area of inflammation with the definite stippling described by Scudder involves the site usually occupied by demonstrable ulcers of the duodenum. Roentgen-ray and fluoroscopic examination in these cases of duodenitis without demonstrable ulcers present findings typical of those in cases of ulcer of the duodenum.

In the associated pathologic lesions, a dilated jejunum was noted ten times in 151 cases, obstruction was mentioned seventeen times, and varying degrees of adhesions seventy-eight times. Lesions in the appendix were recorded in nineteen cases, and in the gallbladder in seven. In one case there was a large diverticulum of the duodenum.

Symptoms. If, after a gastro-enterostomy for gastric or duodenal ulcer, a patient has a return of the same symptoms, or symptoms similar to the original, gastrojejunal ulcer, should be suspected, especially if the recurrence is within a year of the primary operation. The symptoms may recur immediately after gastro-enterostomy or as late as eleven years afterward. In the eighty-four cases of gastrojejunal ulcer reported by Eusterman, the symptoms never entirely disappeared after gastro-enterostomy in 30 per cent, recurred within six months in 35 per cent, within the second six months in 21 per cent, and after one year in 14 per cent. In 146 cases of gastrojejunal ulcers collected by Bryan, symptoms recurred within six months after gastro-enterostomy in 50, within the second six months in 22, within the second year in 23, between the second and fifth years in 20, and between the fifth and tenth years in 13. In 75 per cent of the seventy-five cases of gastrojejunal ulcers collected by Schuldt, there were recurrences of symptoms within two years after gastro-enterostomy. A patient who had had a gastro-enterostomy for duodenal ulcer in 1909 at the Mayo Clinic was completely relieved for eleven years, and then had a recurrence of symptoms similar to those of his original complaint. In January, 1923, he returned to the Clinic for advice, and a secondary operation was performed. A definite jejunal ulcer was found in the proximal loop of the intestine about 1 inch above the stoma of the gastro-enterostomy. Mann, in a series of experiments on animals, observed that all ulcers of subacute or chronic type were found two or more weeks postoperatively, usually developing from three to four weeks after operation, while all but two animals coming to necropsy less than two weeks after operation did not have ulcers.

The onset is insidious in gastrojejunal ulcers, and in untreated cases the course is rapidly progressive. The periodicity is less pronounced than in the previous complaint and the remissions become shorter and more frequent. Eventually the patient has constant symptoms not influenced by medical management.

Pain of various types is the predominating symptom; it may be gnawing, burning, cramp-like, sharp, dull, or merely a distress. There may be no pain in some cases, and in these the only findings may be evidences of bleeding, diarrhœa, constipation, and anæmia. The onset of pain may occur definitely after meals or may be quite independent of the ingestion of food. There is a tendency for the pain to appear earlier after meals than in the original complaint. The pain is noticeably exaggerated by exercise, especially twisting and bending, particularly if there are adhesions; this fact is of some diagnostic importance. The pain in gastrojejunal ulcers is usually located lower than in gastric or duodenal ulcers, being near the level of the umbilicus and to the left of the middle line in a large percentage of cases. It is often associated with tenderness and rigidity over the site of the pain. Distress at night may be a predominating and very annoying feature.

Food relief is very indefinite; it may occur in some cases and be absent in others. Relief by ingestion of food may be experienced for a period early in the course of the disease and be entirely absent later, while in some instances food may relieve the distress at one time, and cause it at another. Eventually food relief disappears and the patient fears to eat; this often leads to great loss of weight, much more than is usual in cases of gastric or duodenal ulcers. Postural ease is often obtained by patients who are not relieved by other means. Nausea, vomiting, belching, and flatulency in varying degrees may be concurrent conditions.

A certain type of gastrojejunal ulcer, in which persistent bleeding is the important finding, may present few or no subjective symptoms. If a patient who has had a gastro-enterostomy for gastric or duodenal ulcer later becomes anæmic, with melæna or hæmatemesis, or both, gastrojejunal ulcer should be suspected. Of the eighty-four cases of gastrojejunal ulcer reported by Eusterman, eleven had frank hæmorrhage, and in only two of these was there a history of preoperative bleeding. Seven of fifty patients with gastrojejunal ulcers operated on at the Mayo Clinic between January, 1921, and April, 1923, gave definite histories of hæmatemesis and melæna. Late hæmorrhage after gastro-enterostomy is a strong presumptive evidence of gastrojejunal ulcer.

In cases in which the ulcer has perforated into the colon, rapid emaciation is noted, depending on the size of the perforation. Diarrhœa, undigested food in the stools, belching of foul gas, and fæcal vomiting, are pathognomonic of gastrocolic or jejunal colic fistula.

In cases complicated with obstruction, perforation, or hæmorrhage, the predominating symptoms and findings will be those of the complication.

Diagnosis. In making a diagnosis of gastrojejunal ulcer it is highly desirable to know what was found at the primary operation. The laboratory findings are not definite. The gastric analysis presents nothing characteristic. In the last fifty cases of gastrojejunal ulcer in which operation was performed at the Mayo Clinic, the average total acidity was 54.5 and the free hydrochloric acid 36.3. The highest total acidity was 122, and the lowest 12; the highest determination of free hydrochloric acid was 112, and the lowest 0. The amount of gastric content averaged 172 c.c., the hightest being 800 and the lowest 50 c.c.

The Roentgen ray[4] is a valuable aid in the diagnosis of gastrojejunal ulcer. At fluoroscopic examination, palpation often elicits pain and tenderness directly over the stoma of the gastro-enterostomy, or over the jejunum, according to the location of the ulcer. The most important Roentgen-ray findings are deformities of the contour of the stoma, irregularities in the jejunum, and enlargement of the stomach.

A recurrence of symptoms after gastro-enterostomy for ulcer may mean gastrojejunal ulcer, persistent activity of the original ulcer, the formation of a new ulcer, disease in the appendix or gallbladder, malignancy, especially in cases of gastric ulcer, or errors in operative technic such as a misplaced stoma, or one that is too large or too small. A diagnosis of gastrojejunal ulcer can probably be made if there is a recurrence of the same or similar symptoms with decreased periodicity and remissions, variable food relief, pain at night, and pain lower in the abdomen than before, especially if this pain is exaggerated by exercise. Emaciation and a history of hæmorrhage with positive Roentgen-ray findings are supporting factors.

If a gastrocolic or jejunocolic fistula exists, the symptoms will be diarrhœa, food in the stools, belching of gas, and fæcal vomiting, while rapid emaciation with fæcal vomiting and undigested food in the stools is pathognomonic. A direct diagnosis can be made with the Rœntgen ray in a large percentage of these cases.

Treatment. Prophylaxis should be the first consideration. In performing gastro-enterostomy one should avoid all trauma as much as possible and secure good coaptation of the mucous membrane. To avoid a stricture at the stoma, the edges of the opening in the transverse mesocolon should be sutured to the stomach some distance from the line of anastomosis. To prevent the line of anastomosis from coming in contact with the colon, it is well to make the opening in the transverse mesocolon as near the root of the mesocolon as possible. A diseased gallbladder or appendix should be removed at the time the gastro-enterostomy is performed.

Medical management may be tried, but if it is not effective, surgery must be employed. A strict, prolonged postoperative diet should be adhered to, minimizing all possible trauma to the stoma as food passes through it.

The operative procedure must be determined in accordance with the operative findings. If the duodenum and jejunum are freely patent, the gastrojejunal ulcer may be excised and the jejunum and stomach closed, leaving normal relations. If, however, the duodenum or jejunum is not freely patent, the gastrojejunal ulcer must be excised, the stomach closed, and a new gastro-enterostomy performed, of the posterior type if possible. In cases in which the duodenum is partly patent, the gastro-enterostomy may be taken down, the jejunal ulcer excised, the jejunum and stomach closed, and some type of pyloroplasty performed. It is not always necessary to take down the old gastro-enterostomy if the ulcer is definitely located at a considerable distance from the stoma in the jejunum. This ulcer may be excised or a portion of the gut resected and closed without operative interference with the gastro-enterostomy. Whatever method is employed, it is desirable to excise the ulcer in all cases, and to alter the physiology of the stomach and jejunum as little as possible. Alapy advises pyloroplasty with excision of the ulcer, rather than gastro-enterostomy, in order to retain the normal physiology of the duodenum. In Germany, partial resections and pyloroplasties with excision of the ulcers are being performed more and more for benign ulcers of the stomach and duodenum.

Sixty-five per cent of the patients are either cured or satisfactorily improved. A large percentage returning with symptoms after gastro-enterostomies have had the operation performed when ulcer had not been definitely demonstrated. Eighteen of the 151 patients with gastrojejunal ulcer presented no evidences of primary ulcer; results in these cases have not been satisfactory. The percentage of patients with gastrojejunal ulcers that will recur cannot be foretold, but it is reasonable to assume that the so-called ulcer-bearers will have a return of symptoms. The postoperative results will be improved as soon as an operative procedure has been devised which does not alter the physiology of the jejunum.

Discussion. Jejunal ulcers have been more common in the past than they probably will be in the future. The importance of the mechanical arrangement of the jejunum is now fully recognized; for example, the jejunum should be anastomosed to the stomach in such a manner as to obtain a properly functioning gastro-enterostomy, which will reduce the probability of the formation of secondary ulcer as much as possible. In many cases the postoperative history indicates some difficulty with the gastro-enterostomy soon after it was made, and at intervals thereafter. More accurate approximation of the mucous membrane of the stomach and intestine will tend to reduce the number of hæmatomas forming in the suture line, and prevent the irritation and erosion of the tissues resulting from their exposure to the acid chyme.

It has been noted that in many cases of secondary ulcers the loop of jejunum is greatly dilated; it is not tense and distended as in the presence of obstruction low in the jejunum, but is relaxed and flaccid, and seems to be in a state of paresis. In certain instances, this condition may be due to severance of the nerves to the musculature of the intestine when the gastro-enterostomy was made, or this distention may result from the passage of foods and unchanged gastric secretions directly into a loop of intestine unaccustomed to receiving them. It has been suggested that this is the manifestation of an attempt, on the part of a loop of intestine, to accommodate itself to conditions similar to those of the stomach. Dilatation of the loop distal to the gastro-enterostomy stoma is rarely, if ever, seen unless a jejunal ulcer develops, but is always present to some degree in the cases of secondary ulcer.

Diet and alkalinization, begun immediately after gastro-enterostomy, have not always succeeded in preventing the formation of secondary ulcers; as a matter of fact, we have observed several patients in whom the ulcers formed under these conditions. The treatment which usually relieves the symptoms, and which, in some cases at least, has an effect on the primary ulcer, will not prevent the formation of jejunal ulcer. The formation of secondary ulcers while the patient is observing strict dietary precautions occurs so often that the advisability of continuing rigid management for any length of time after a gastro-enterostomy is questionable. Evidence of a secondary ulcer often presents itself soon after a marked indiscretion in diet, so that some precaution would seem to be advisable. Routine medical treatment may be of some avail if the symptoms are mild and not of long standing, but often little is accomplished by it. These patients are rarely relieved by food and soda, and but little, therefore, can be expected from the medical régime.

Jejunal ulcer usually penetrates the coats of the intestine, but it may be walled off by the attachment of the surrounding tissues. We have not seen a case of complete perforation into the peritoneal cavity with acute symptoms, although a considerable number of such cases have been reported in the literature. The jejunum is greatly deformed, the mesentery of the colon edematous and markedly thickened and shortened, so that the colon is pulled down toward the anastomosis. It readily becomes attached to the tissues at the stoma, and not infrequently the perforation produces a communication between the jejunum and the colon; or possibly the stomach, jejunum, and colon communicate through one large opening. We have operated in thirteen cases of this type. Usually, the ulcer itself is not large, or there may be several small lesions, but the amount of infection in the surrounding tissues is often sufficient to produce a large tumor with the adjacent structures pulled into it. At first it may appear that the only procedure is to resect the involved portions of the stomach and large and small intestines. This is usually unnecessary, however, as it will be possible to separate the structures and expose the anastomosis and the ulcer; although considerable experience is required to work out a satisfactory plan of procedure. Formerly, it was thought best to excise the jejunal ulcer and reconstruct the anastomosis. The rapid formation of other jejunal ulcers has proved this plan to be inadvisable, and a jejunal ulcer is now recognized as evidence that a gastro-enterostomy will probably never be satisfactory. We have obtained better results by taking down the gastro-enterostomy and excising the jejunal ulcer, closing the openings in the stomach and jejunum, and at the same operation excising the original ulcer and making a plastic operation on the pylorus, if necessary. Some of the patients have not been entirely relieved; others have had a recurrence of symptoms, sometimes after an interval of relief. We are inclined to believe that in the future there will be more resections of the pyloric end of the stomach including the original ulcer (if possible) in cases in which a jejunal ulcer has once formed. Secondary ulcers very rarely form after resection of the stomach, and the results have been very good in the few cases in which we have carried out this procedure for jejunal ulcer. No matter what plan is adopted, the operative procedure will carry a serious risk, but the risk probably will be no greater in those cases in which a resection is performed than in those in which a plastic operation is done, and the ultimate results promise to be much better. The gastro-enterostomy must first be taken down, the jejunal ulcer excised, and this portion of the jejunum reconstructed. There is usually much edema in the tissues, and usually the loop of intestine is very large and deformed, but it is nearly always easier to close the opening in it than to resect it. A portion of the stomach on the pyloric side of the opening is removed with the ulcer. The duodenal stump being closed, the resection may be completed as a Polya operation, or a Billroth II. Perforation of the ulcer into the colon does not add greatly to the operative procedure, as the colon is readily separated from the inflammatory mass, and the opening closed.

Operations for secondary ulcers are likely to be long, tedious and extensive. There may be soiling from the stomach and intestine, although this can usually be avoided by the use of rubber-guarded clamps. The immediate results have been surprisingly satisfactory in cases in which the operation was undertaken when the patient was not too greatly reduced from starvation and suffering. Often the risk can be decreased by the administration of fluids, and possibly by rectal feeding, for a number of days before the operation. The best ultimate results will be obtained by removing the pyloric end of the stomach with the original and secondary ulcers.

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FRACTURES AT THE HIP JOINT

By ROYAL WHITMAN, M. D.

FRACTURE OF THE NECK OF THE FEMUR

Fracture of the neck of the femur may be considered from two standpoints, which, for comparison, may be termed the old and the new. The old, or established, conception is that the fracture is an exception to all others, in that treatment on surgical principles is in most instances both dangerous and futile.

This point of view is very clearly presented in the following quotation from a leading treatise on fractures:

" The ideal object of treatment, restoration of form and function, is rarely to be attempted or even sought." " The first indication is to save life, the second to get union, the third to correct or diminish displacements." These indications are simply a modern expression of the teaching of Sir Astley Cooper formulated more than one hundred years ago, that an intracapsular fracture was practically incapable of repair. He admitted, however, that the primary cause of nonunion, as in fractures of the patella and olecranon, was separation of the fragments. For, in his own words, " the neck of the thigh bone when broken is placed under similar circumstances (to the fractured patella), for by contraction of the muscles, it is no longer in apposition with the head of the bone and is therefore prevented from uniting. If this, however, were the only obstacle, it might be argued that retraction of the thigh bone could be prevented by bandaging and extension, the truth of which cannot be denied, but it is scarcely possible even for a few hours to preserve the limb in such apposition, as the patient on the slightest change of posture produces instant retraction by bringing into action the powerful muscles which pass from the pelvis to the thigh bone."

The mechanical inadequacy of external appliances to provide the opportunity for repair is explained by the shape of the femur. For, since the neck projects laterally from the shaft, splinting and traction can at best appose the fragments only in a lateral and therefore unstable relation. This inadequacy is the basis of the teaching that treatment should be directed to the individual rather than to the injury. To save life one may disregard the fracture altogether. If it is intracapsular, treatment is futile unless it is impacted, when it should be protected.

If it is extracapsular, repair is the rule, yet no attempt should be made to correct resistant deformity, since " to break up an impaction is a surgical crime."

Function other than the capacity for weight bearing has received no consideration whatever, even from an analytic standpoint.

The typical chapters on fracture of the neck of the femur in the text books have varied but little in succeeding generations. Much space is given to descriptions of specimens, manifestly atypical, since they represent fatality, and to the differential diagnosis of the type of fracture to which the treatment is to be adapted. The main purpose, however, seems to be to present all the obstacles to success, physical, nutritive and mechanical, in order to uphold treatment of a quality that would not be tolerated for any other fracture, and to explain failure on other grounds than the lack of opportunity for repair.

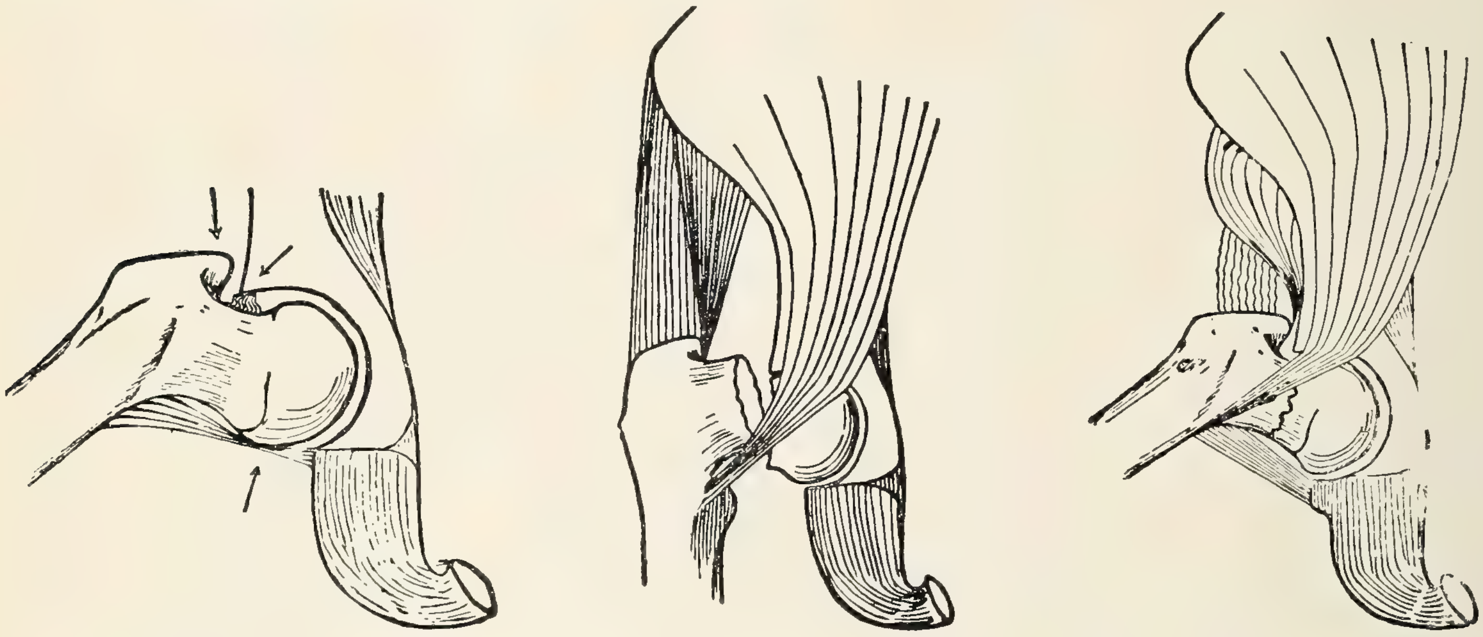

FIG. 1. The limitations of normal abduction

FIG. 2. The characteristic displacement after complete fracture

FIG. 3. The mechanism of the abduction method in assuring security

FIG. 423. The evolution of the abduction treatment. Original diagrams illustrating the mechanism of the method applied for complete fracture, 1902. (Courtesy of Annals of Surgery)

Treatment conducted in accord with this teaching has been naturally of a most perfunctory character, indeed, it is stated in a recent paper that, of 120 consecutive cases of ununited fracture at the hip examined at the Mayo Clinic, not one had received efficient treatment at the time of the injury.

Even in cases in which the fracture, as distinct from the individual, has been treated the results have been extraordinarily bad, as evidenced, for example, by the report of the British Committee, in which they were classed as good in but twenty-three per cent. of the cases examined.

The new conception is based on the abduction method, by which the anatomical construction of the hip joint, thus far an insuperable obstacle to efficient treatment by routine methods, has been utilized to correct deformity and to appose and fix displaced fragments; in other words, to assure the essentials of functional repair.

The neck of the femur projects upward and forward from the shaft. This upward inclination permits abduction of the limb until the neck lies in an approximately horizontal plane, when the movement is checked by contact of the upper border of the neck with the rim of the acetabulum, by tension on the capsule and by contact of the trochanter and the pelvis. In fracture of the neck of the femur, the inner fragment, over which one has no direct control, is a practically fixed point to which the shaft fragment may be adjusted. In this procedure the fragments are first brought into lateral apposition by direct manual traction and inward rotation; the limb is then abducted to the normal limit when the tension on the capsule must align the fragments when brought end to end in a horizontal plane. Security is thus assured by direct mutual pressure of the fragments, by the tense capsule which encloses each, and, if the fracture is near the head, by its inclusion within the acetabulum. Finally, the muscles, whose spasmodic action Sir Astley Cooper thought it impossible to control, are relaxed and impotent. It only remains to fix the limb in this attitude to assure this internal or anatomical splinting. (Fig. 423)

This introduction, contrasting the mechanical efficiency of the abduction or anatomical method with those dependent upon external appliances, should make it evident that the precepts adapted to inadequacy may be disregarded and that one is now free to consider fracture of the neck of the femur from a new or rational standpoint.

The neck of the femur is a weak point in the skeleton because it projects laterally from the shaft. It may be broken at any age; the two most susceptible periods being adolescence, when the epiphyseal junction is weak, and old age, because the mechanically weak point, participating in the general atrophy of the bones, and with lessened muscular protection, becomes relatively more vulnerable to the strains and falls incidental to locomotion.

The intrinsic and extrinsic obstacles to successful treatment are self-evident. Many of the patients are in poor physical condition. The neck of the femur is a terminal bone, dependent in great degree for its nutrition on blood supply from the shaft side of the fracture. The fragments of a transcervical fracture are of small area and there is practically no periosteal callus formation. On the other hand, experience with the abduction method has long since demonstrated that efficient treatment of the fracture is the most conservative treatment of the patient, that repair is both possible and probable in every type of fracture if opportunity is assured, and finally, that in no fracture can surgical principles be more easily and efficiently applied. In other words, " the ideal object of treatment, restoration of form and function," has now become a practicable routine and the obstacles to success which thus far have served to excuse neglect and to explain failure have become incentives to efficient treatment, on the self-evident proposition that the less capacity for repair the more directly is it dependent upon favorable opportunity.

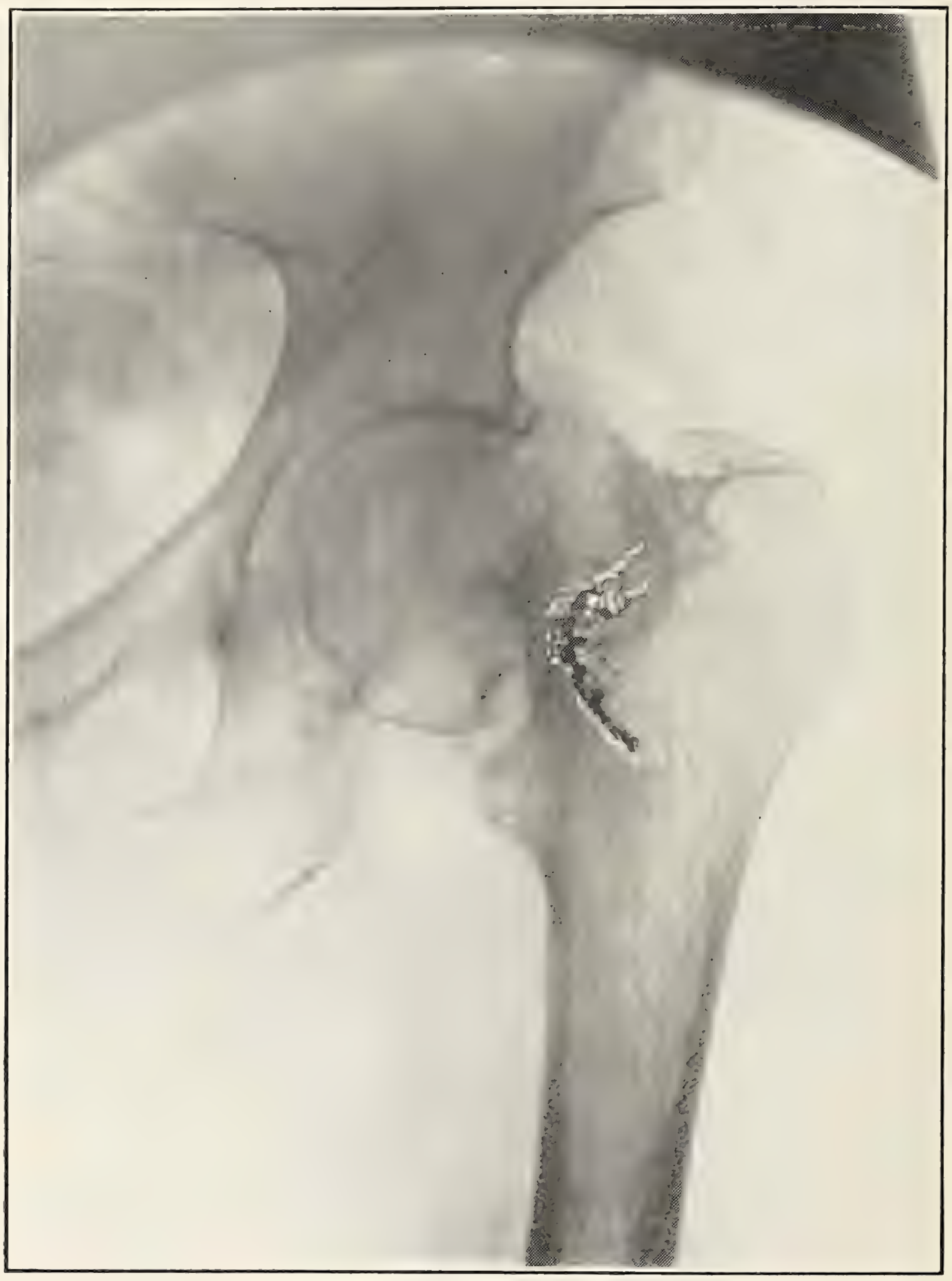

FIG. 424. Transcervical Fracture illustrating upward and outward displacement of the shaft fragment and apparent shortening of the neck.

As all types of fracture are now treated by the same method and with the same purpose, the location of the fracture is of no particular importance except as it concerns prognosis, and for exact diagnosis X-ray examination has practically supplanted the interpretation of physical signs.

In vigorous life the fracture may be at any part of the neck and if near the base it is often incomplete. It has been the general impression that the typical fracture of elderly subjects is intracapsular but X-ray examination has shown that in a large proportion of the cases it is at the base; consequently, the prognosis for union is more favorable than has been supposed.

In childhood the fracture is often incomplete, the neck of the femur having been forced downward and backward in its relation to the shaft. In adolescence, the epiphyseal junction is the most vulnerable point, the head being displaced downward and backward on the neck. The displacement may be practically complete as after severe injury, or partial and progressive as in what has been termed epiphyseal coxa vara.

It may be noted that the characteristic deformity of the incomplete fracture is downward and backward displacement of the neck on the shaft. The loss of the upward inclination limits abduction and inward rotation and it is the usual cause of what is called apparent shortening of the limb and consequent disability, even when bony union has been attained.

The surgical axiom, that deformity should not be disturbed, is based on the inadequacy of the means at command to appose the fragments if separated by the " breaking up of the impaction." In this connection it may be noted that the popular impression of an impaction as a secure contact of the fragments which should assure repair is an ancient conception based on a fanciful interpretation of the physical signs. Incomplete fracture in the neighborhood of the trochanter or at the junction of the head and neck are not uncommon but the shortened neck, seen in the X-ray pictures of the transcervical fractures (Fig. 424), usually indicates an overlapping of the fragments rather than a telescopic impaction and, therefore, a separation rather than an apposition of the fractured surfaces.

As has been stated, the situation of the fracture concerns prognosis rather than treatment. In fractures at the base of the neck repair is practically assured and restoration of the normal contour, in order to assure functional recovery, is the chief concern.

In transcervical fractures a certain absorption of tissue is common. This, however, may not prevent eventual union if contact is maintained for a sufficient time. In fractures of this type repair is an interstitial process practically unaided by external callus, and Rhode's investigations[1] indicate that complete fixation such as may be assured only by the abduction method is essential to union since the slight movement between the fragments permitted by traction, even when efficiently applied, will prevent repair.

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[1] Surg., Gyn., and Obst., December, 1925.

Diagnosis. The symptoms of a complete fracture of the neck of the femur are so characteristic that there should be little question of diagnosis. If a patient falls and is unable to rise, in the absence of other obvious injury, a fracture at the hip is almost certain. It is true that in some instances of incomplete or impacted fracture locomotion has been possible after the accident, especially in childhood, but even in these cases the disability is far greater than could be explained by a strain or bruise.

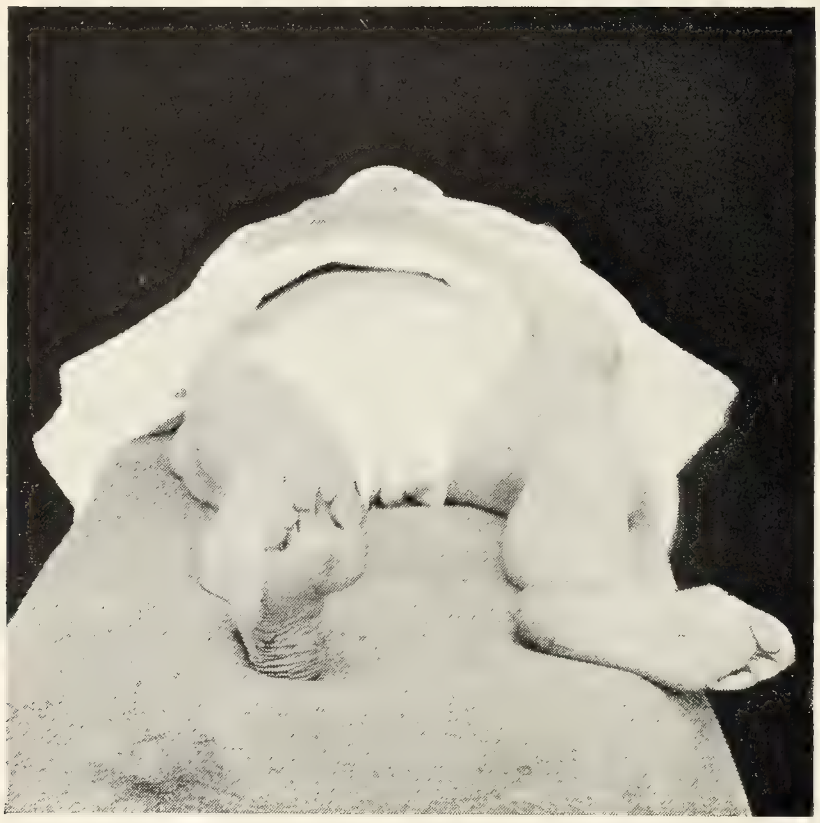

Fig. 425. The attitude typical of complete fracture of the neck of the femur. The patient is a woman, eighty-five years of age. See Figs. 426, 427 and 428. (Courtesy of Annals of Surgery)

In practically all cases of incomplete fracture there is an elevation of the trochanter in its relation to the head of the femur. Or, in other words, the neck has been forced downward and backward on the shaft; consequently, the limb is somewhat shortened and rotated outward, the relation of the trochanter to Nélaton's line and Bryant's triangle is changed, motion is painful and in incomplete fractures particularly restricted in abduction. The X-ray is now generally available and in all doubtful cases, even in the absence of physical signs, such an examination should be made as it sometimes discloses fracture without displacement which, if untreated, would result in deformity.

Treatment. As has been stated, the essential difference between the abduction treatment and other methods is that it utilizes natural, in the place of artificial, splinting; the chief function of the external appliance being to hold the limb in the position that makes the internal splinting effective, and although apparatus such, for example, as the Jones abduction frame or the Bradford abduction brace may be used for this purpose they are so rarely available that the chief dependence must be placed on the plaster spica. This, fortunately, is the most comfortable and efficient of all supports and, for the surgeon qualified to apply it, the treatment of the fracture, even under adverse conditions, is comparatively simple. The only apparatus required is a pelvic rest provided with a perineal bar that may be screwed to the end of a firm table on which is placed a box of equal height to support the shoulders. In hospital practise a table of the Hawley type is used but this is not essential. Complete anatomical abduction requires muscular relaxation, therefore anæsthesia is, in most instances, practically an essential preliminary. This may be rectal or spinal in special cases but, under ordinary conditions, the gas-oxygen and ether anæsthesia is employed.

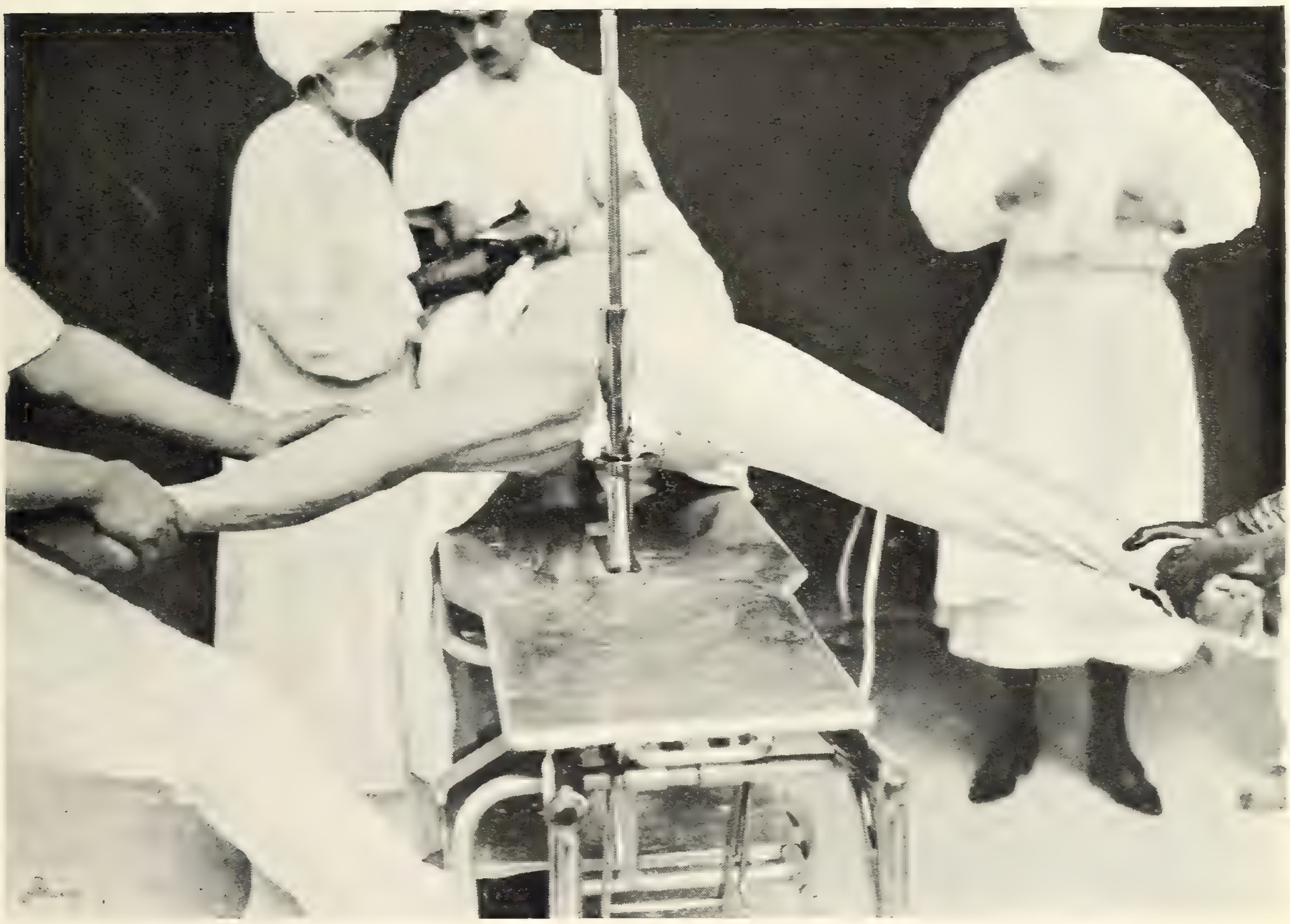

FIG. 426. Illustrates the second stage of the abduction treatment, the fragments having been apposed by direct manual traction and inward rotation, the limbs are abducted to the normal limit. Note the complete extension and inward rotation of the left limb. (Courtesy of Annals of Surgery)

The patient, having been anæsthetized, is placed on the box and pelvic rest, the two extended limbs being supported by assistants who draw the perineum into contact with the upright bar and against this resistance the shortening on the injured side is reduced by direct traction as demonstrated by comparative measurement. The assistant holding the injured limb then rotates it slightly inward, guided by the patella, not the foot. By these manipulations the fragments have been brought into lateral apposition; manual traction still being maintained, the limbs are then abducted to the anatomical limit as demonstrated by the range on the uninjured side. Inspection should then show an absolute correspondence of the anatomical relations of the trochanter on the two sides, the pelvis being level, the limbs completely extended and that on the injured side being rotated inward (Fig. 426). In this attitude the fragments must be apposed end to end in resistant contact. If the fracture is near the head of the bone it will lie within the acetabulum and, finally, muscular contraction, as a cause of displacement, will have been completely eliminated.

The essential requirements for the proper application of the abduction treatment are sufficient familiarity with anatomical landmarks to verify the reduction of the displacement and the complete abduction of the limb to the normal limit upon a level pelvis which alone assures security. One often observes, in the practise of others, that the abduction is apparent rather than real; the pelvis being tilted upward on the injured side. The second essential is the ability to apply a secure and comfortable plaster support to hold the limb in the attitude which makes the internal splinting effective — namely: full extension, full abduction and slight inward rotation, the knee being somewhat flexed to relieve the strain, the foot at a right angle with the leg and slightly adducted.

What is called the long spica, extending from the axillary line to the toes, is the most effective form; the long trunk portion more nearly equalizing the leverage of the abducted limb. Full extension of the thigh tilts the pelvis slightly forward and thus assures the normal lumbar lordosis. It lessens the pressure on the sacral region and, what is of great importance, makes the ventral attitude as comfortable as the dorsal. Freedom of the other limb is of advantage because the patient may aid himself somewhat in changing his position. These points are emphasized because various modifications of the method have been introduced by others. For example, the spica is applied with the thigh flexed a greater or less degree. This has the obvious disadvantage of reducing the lumbar lordosis and increasing the pressure on the sacrum. More often the other thigh is included in the spica. This is essential if the short spica is used but adds an unnecessary restraint of the patient's movements.

The most obvious disadvantage of both methods is the difficulty of turning the patient for ventral recumbency, which in the treatment of the aged is considered of the first importance.

The plaster spica, if properly applied, assures a general, comfortable and secure support free from pressure or constriction. A close-fitting shirting or a "union suit" of underclothing is drawn on and covered by a uniform layer of sheet wadding, bound securely by Canton flannel bandages, the padding being made very thick about the upper part of the chest and the sacral region (Fig. 427). The spica is usually strengthened at the hip by the insertion of one or more thin steel bars. It is then carefully cut out at the pelvis to permit flexion of the sound thigh (Fig. 428) and later an outer covering of shirting is drawn over it and sewed to that next the skin so that all the margins of the plaster are covered by a thick, soft binding (Fig. 429). When the spica has become firm, the patient is placed in bed, the head of which has been raised one or two feet, a board having been placed beneath the mattress to prevent sagging. The elevation of the head in place of the foot of the bed as with the traction treatment, has the great advantage of favoring the processes of digestion, increasing the blood supply at the seat of fracture and lessening the tend-

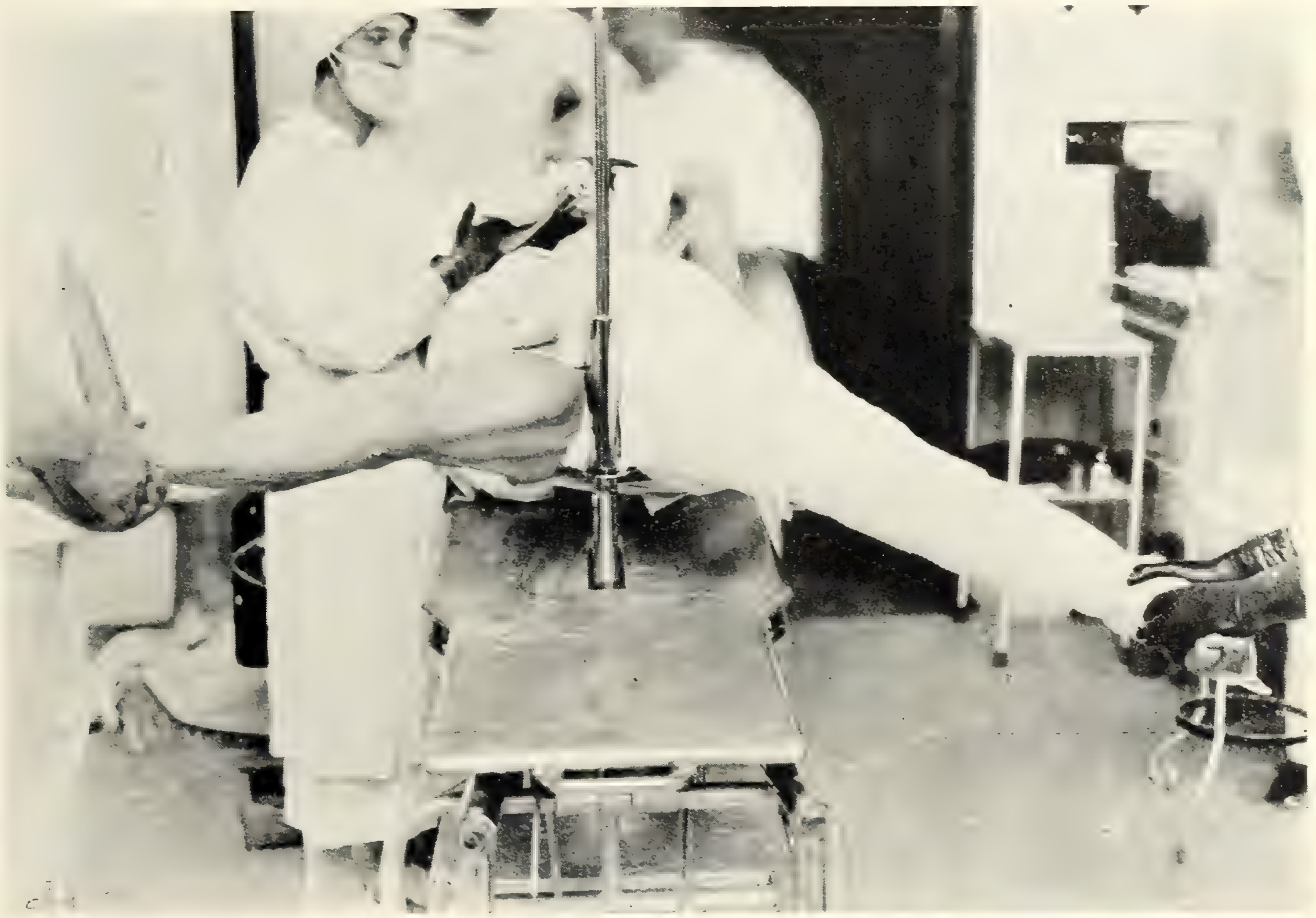

FIG. 427. Illustrates the thick covering of sheet wadding and bandage to protect the skin from pressure. (Courtesy of Annals of Surgery)

ency to congestion of the lungs. As soon as practicable, the patient is turned completely over to the ventral attitude and thereafter at such intervals as may seem indicated (Fig. 430). This removes pressure from the sacral region and is an effective preventive of both bed sores and "hypostatic" pneumonia. The attitude is so comfortable that in many instances the patients pass as much time in one posture as in the other. At the first turning, one should insert the hand between the sacrum and the plaster splint to assure freedom from direct pressure. It may be noted, as one of the great advantages of the abduction treatment, that it is under single control in the sense that the maintenance of the opportunity for repair is not dependent upon the coöperation of the nursing staff. Opportunity implying the fixation of the fragments in apposition for a sufficient time to permit repair, verified by X-ray examination at the time of the operation (Fig. 431) and at intervals thereafter.

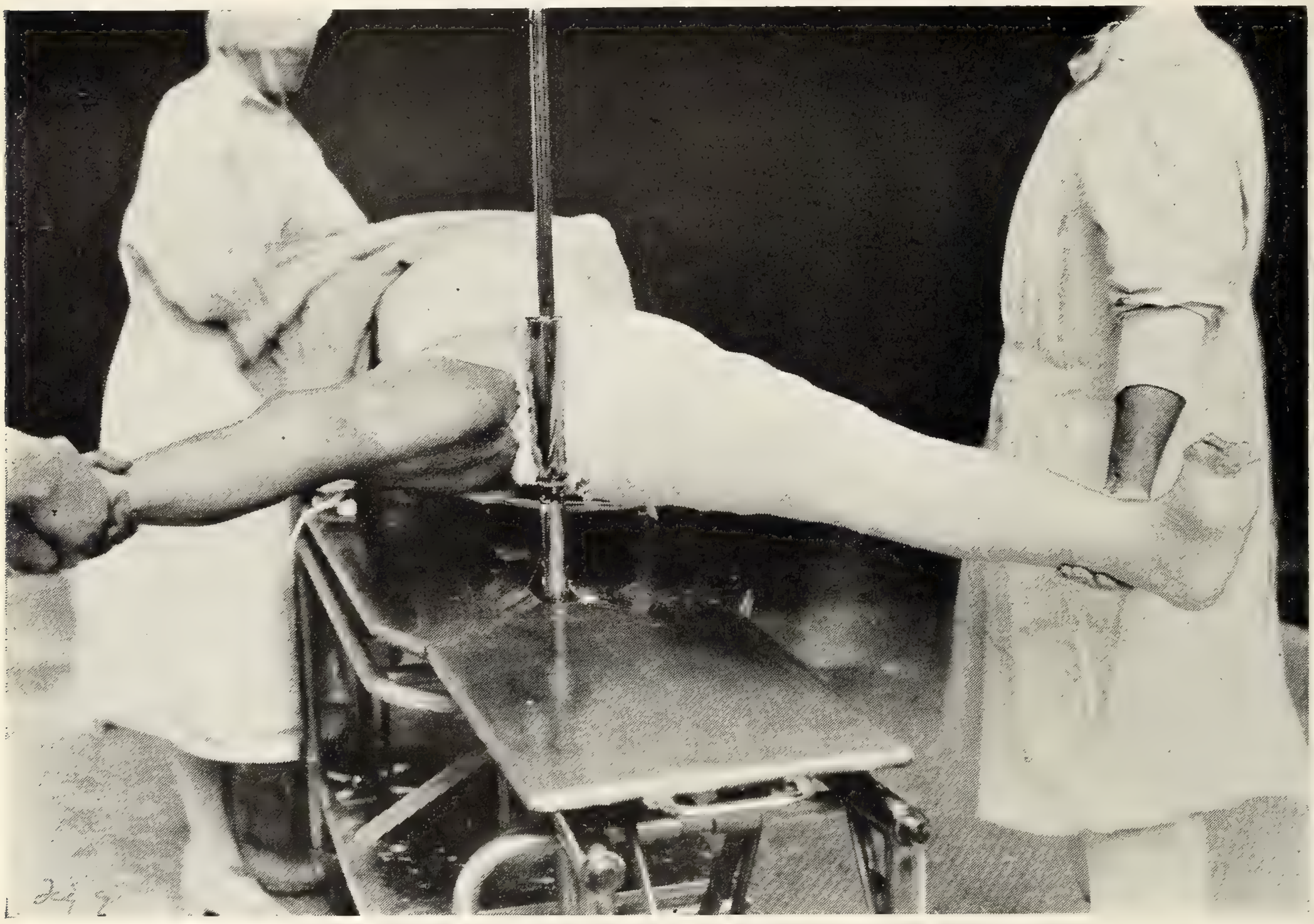

Fig. 428. Application of the plaster spica completed. (Courtesy of Annals of Surgery)

In this description the fracture is assumed to be complete but it applies equally to the so-called impactions which, as a rule, are as readily reduced as in those in which the fragments are separated. The incomplete fractures, which include open fissures through the base and the like, are

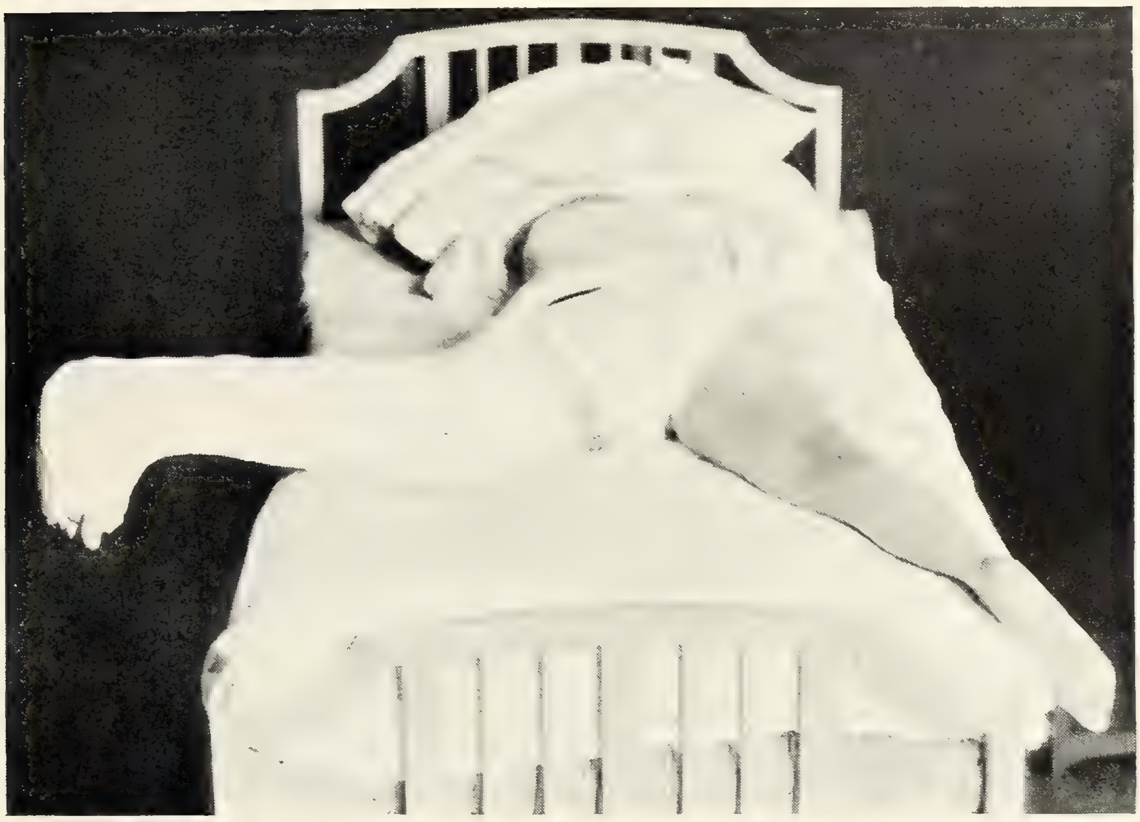

FIG. 429. The ventral attitude and elevation of the head of the bed that prevent the usual complications of the persistent dorsal recumbency required in conventional treatment. An outer covering of shirting has been drawn over the spica and sewn to the inner, thus providing a soft binding for margins of the plaster splint. (Courtesy of Annals of Surgery)

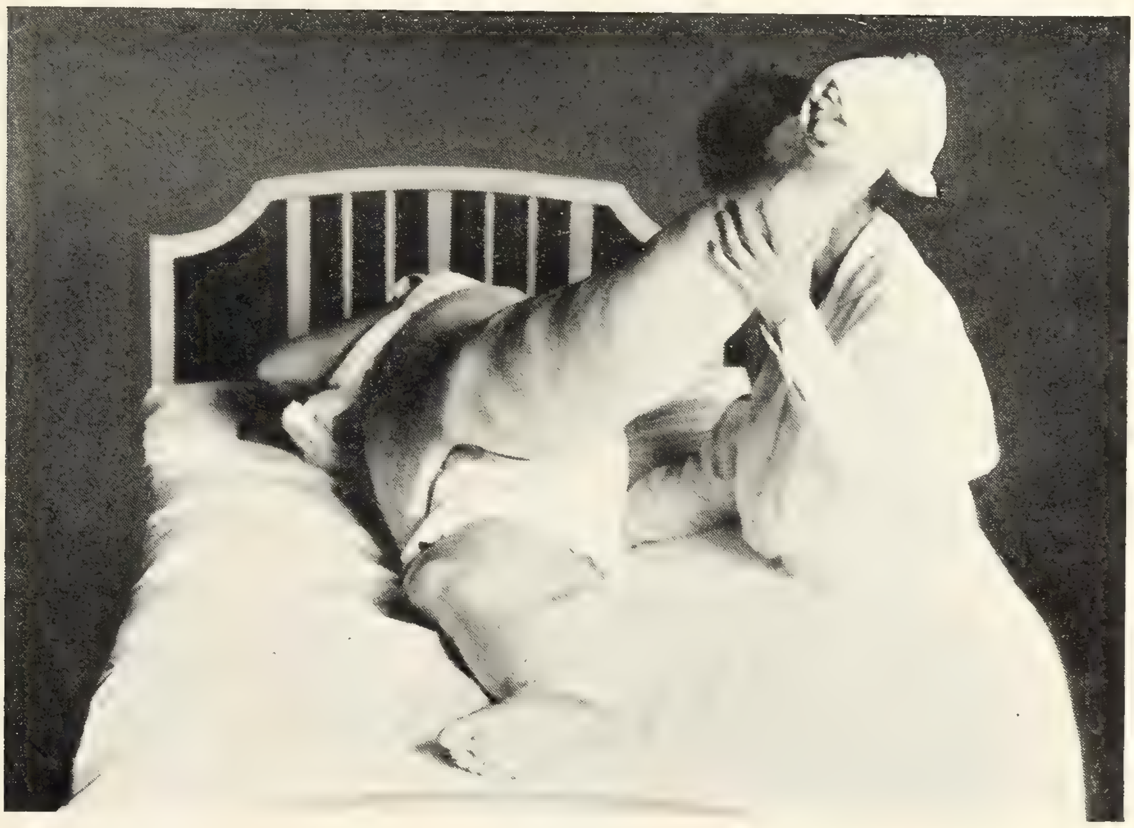

FIG. 430. Turning the patient. At first several assistants may be required to turn the patient easily or, as it were, "in one piece." (Courtesy of Annals of Surgery)

reduced by the same manipulations (Figs. 432, 433, 434). In such cases the neck is usually depressed and forced backward as indicated by elevation of the trochanter and outward rotation of the limb. This deformity places the neck in a relation to the acetabulum that under normal conditions would require abduction and inward rotation of the limb; consequently, by abduction and inward rotation of the limb, the normal relation of the neck and the shaft may be restored. This is easily accomplished by natural leverage. Thus it will appear that "impactions are broken up" only in the sense that fractured surfaces, by correction of the deformity, are apposed and fixed in contact. In those rare cases in which there is a telescopic and resistant impaction one would simply restore the normal angle of the neck and not abduct the limb to the degree that would actually withdraw the embedded fragment.

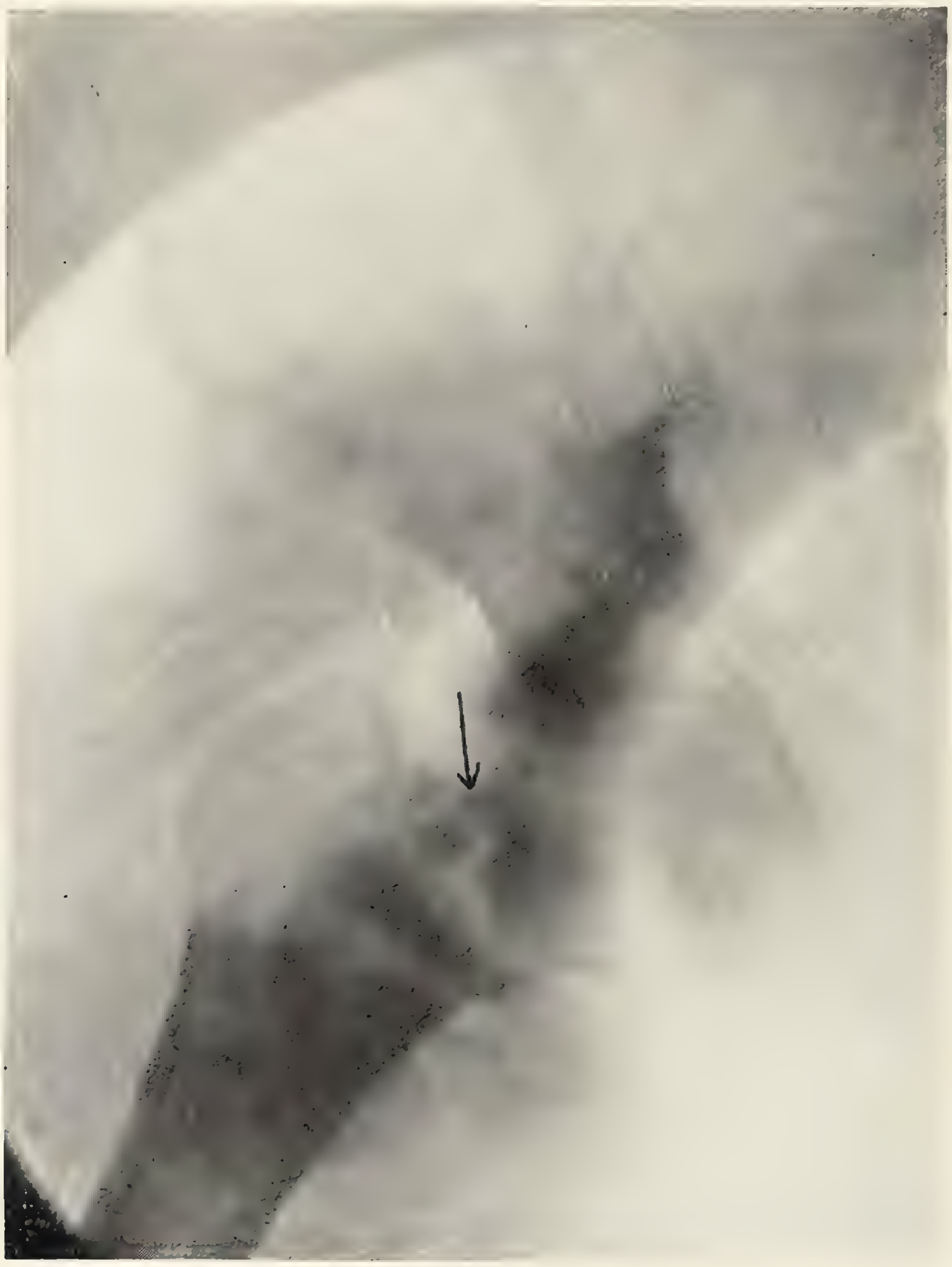

Fig. 431. After the application of the spica, showing adjustment and fixation of the fragments. (Courtesy of Annals of Surgery)

If the plaster spica has been properly applied, and if the fixation of the fragments in normal relation has been verified by X-ray examination, the essentials of success are assured and the nurse is free to devote her time to the care of the patient. It must be impressed upon her that the abducted limb must project from the bed and that the patient must be moved or turned over, as it were in one piece, so that pressure on one or other side of the chest may be avoided. Discomfort from direct pressure is prevented by care in the application of the spica and by the frequent changes in posture that it permits, the patients being turned to the ventral attitude twice daily, or oftener if desired. The elevation of the head of the bed enables the patient to observe the surroundings with only a thin pillow beneath the head. Thus pressure of the splint upon the chest is prevented. If there is complaint of abdominal constriction, an opening

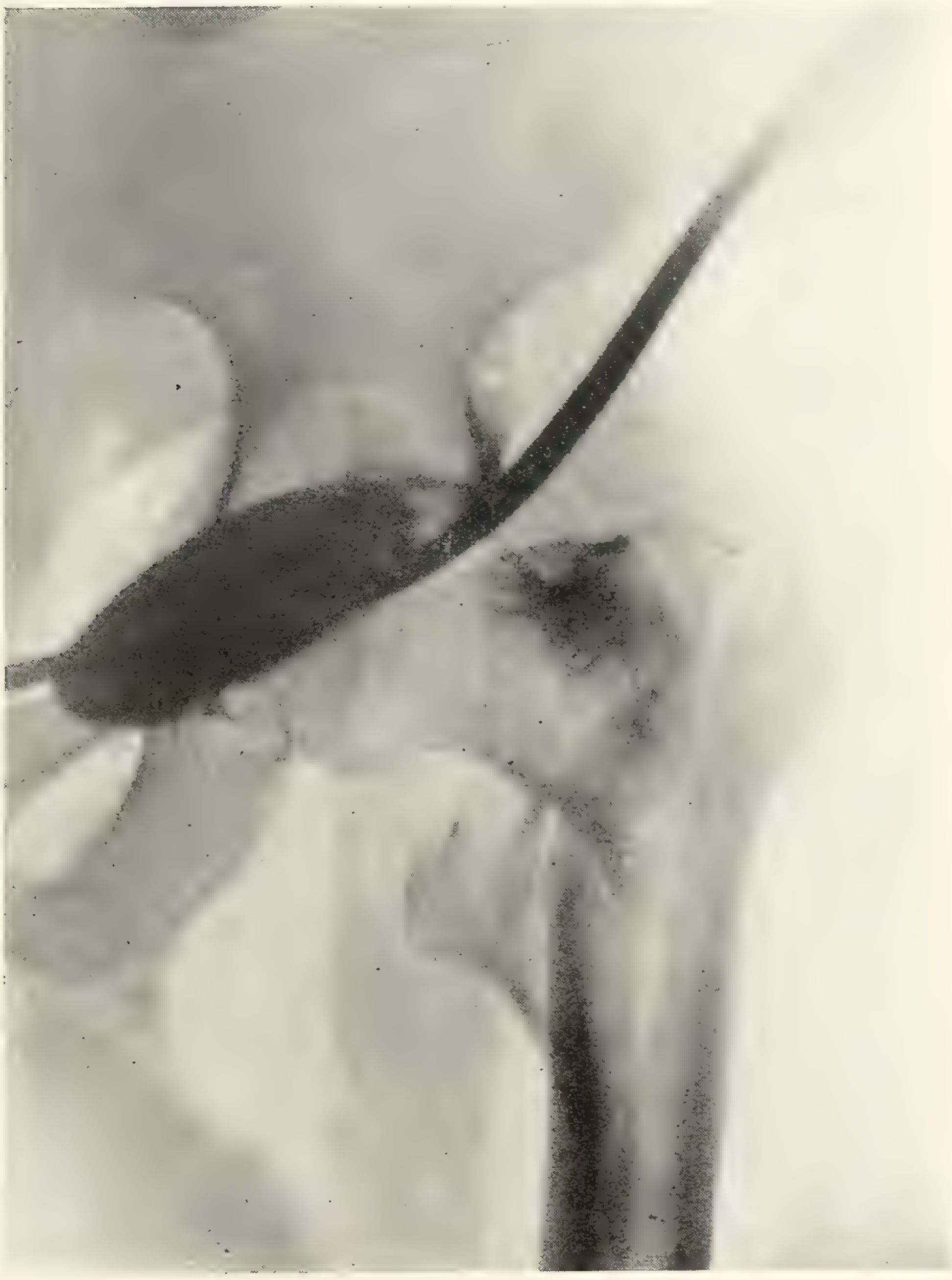

Fig. 432. A shattering fracture at the base, in a man sixty-seven years of age. See Figs. 433 and 434. (Courtesy of Annals of Surgery)

may be made over the region of the stomach and, if the lateral walls are strengthened, the entire front may be cut away leaving only the pelvic portion so that the upper part of the trunk may be lifted at intervals. This, however, is rarely indicated.

It may be noted that, in contrast to fractures involving other joints in which motion if resumed as early as possible, complete fixation for a long period is required. This is absolutely essential to the repair of the trans-cervical fracture and is advisable for fracture at the base because of the great strain of movements of the limb and in order to prevent the exuberent callus formation so often observed in museum specimens, although this may be due in great part to unreduced deformity and early weight-bearing. The plaster spica is retained, usually, for two months for fractures at the base and for three months for those of the intracapsular type. In some instances the plaster support is cut away at the knee in order to

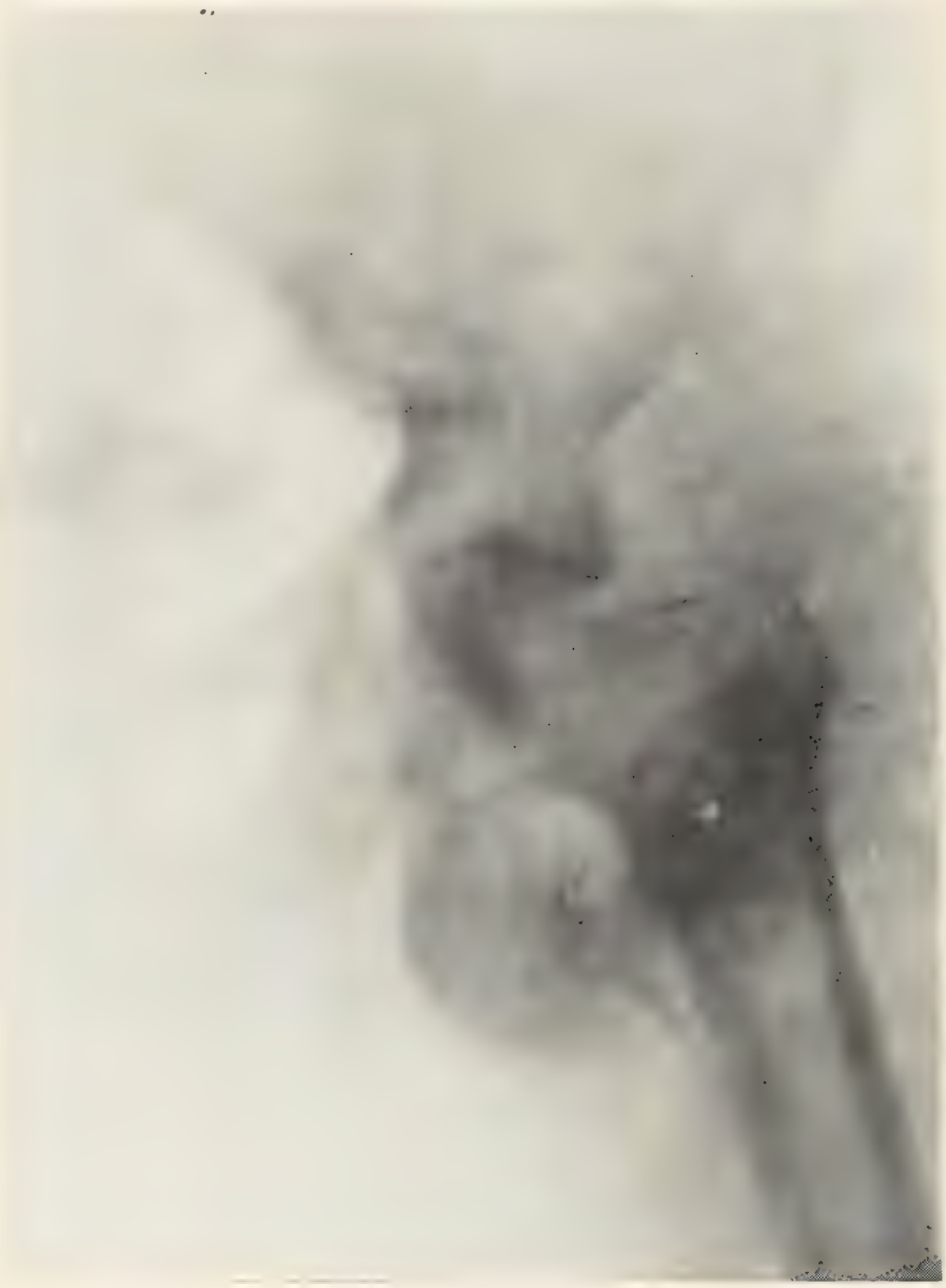

FIG. 433. Taken through the spica. (Courtesy of Annals of Surgery)

permit motion at that joint. This, however, is of doubtful advantage since the leg often swells after the constraint is removed. At the end of the fixation period, determined, if possible, by X-ray examination, the spica is bivalved, the patient remaining for a few days in the lower half and after complete removal should, if possible, remain in bed for several weeks for massage and for active and passive exercises (Fig. 435). Motion at the knee joint is limited for a time but is usually regained long before full weight-bearing is permitted. The most important injunction is that the attendant shall abduct the limb at least twice daily to the normal limit, otherwise the range of movement in this direction will become restricted even within a few days. Loss of abduction, practically inevitable under the old system of traction in the line of the body, is one of the chief factors in the limp formerly supposed to be the invariable result of the injury.[1]

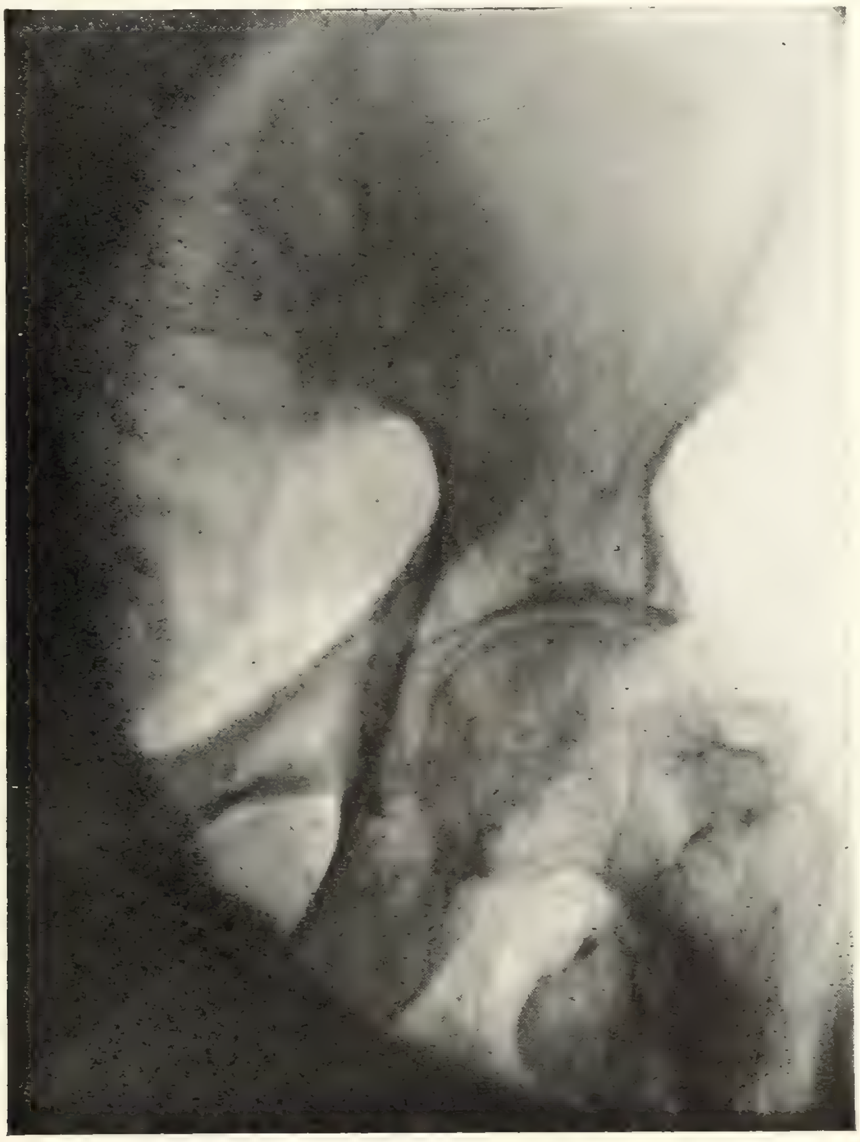

FIG. 434. The final result, the important point being the restoration of the angle of the neck. This patient was presented before the Surgical Society eight months later to illustrate a perfect functional recovery. (Courtesy of Annals of Surgery)

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[1] "No matter whether the fracture has taken place within or external to the capsule, whether it has united by ligament or bone, shortening of the limb and lameness are the invariable result." (R. W. Smith).

When sufficient time has elapsed to assure stability of repair, when a fair degree of voluntary control has been regained, and when the physical indications of union have been verified by X-ray examination, locomotion on crutches is begun, but for many weeks no appreciable weight-bearing is permitted. In younger subjects or in urgent cases a brace to permit locomotion without weight-bearing may be applied. This may be of the Thomas caliper type or, preferably, the ordinary caliper extension hip brace. It is only by the complete reduction of deformity at the time of operation and by persistent and intelligent after care, both of which have been lacking in the past, that restoration of function can be assured.

The question of union or nonunion, now that opportunity, as it has been defined, may be verified, is simply of the capacity of the tissues for repair. One may reject, therefore, all the conclusions based on clinical experience in the past or on studies of anatomical specimens as essentially speculative. Union is possible and even probable in any type of fracture if the initial opportunity is provided.

This statement is amply supported by clinical experience. One may cite, for example, the statistics of Waldenström [1] as fairly representative and thoroughly verified. By the abduction treatment, union was obtained in 55 per cent. of the cases of intracapsular fractures. Better results have been reported by many other surgeons. Lotberg,[2] Campbell [3] and Portwich-Deutsch [4] report bony union in upwards of 90 per cent. treated by the abduction method.

It may be emphasized in this connection that, according to the old teaching, these fractures were incapable of repair, and treatment, therefore, was futile.

The new proposition is that since it is impossible to determine in advance the cases in which failure is inevitable, all should be assured the opportunity for repair, otherwise the surgeon should be held responsible for the inevitable result.

Furthermore, that since the larger proportion of the fractures are near the base of the neck where union is practically certain, the prognosis of fracture of the neck of the femur, considered as an entity, both as to life and function, under efficient treatment is distinctly favorable.

Primary operative treatment by the insertion of nails or screws or bone pegs has been advocated in the past as the only means of fixing the fragments. It is evident, however, that a peg of whatever material cannot increase the blood supply but will rather lessen the nutritive capacity by injury to the cancellous structure and, if absorption of a part of the neck follows, the fragments will be held apart by the means designed to appose

[1] J. de Chir. August, 1924.

[2] Acta. Chir. Scand. Dec. 31, 1924, 67 per cent.

[3] Annals of Surgery, November 1919.

[4] Zeits. F. Chir. B 193 — 1925.

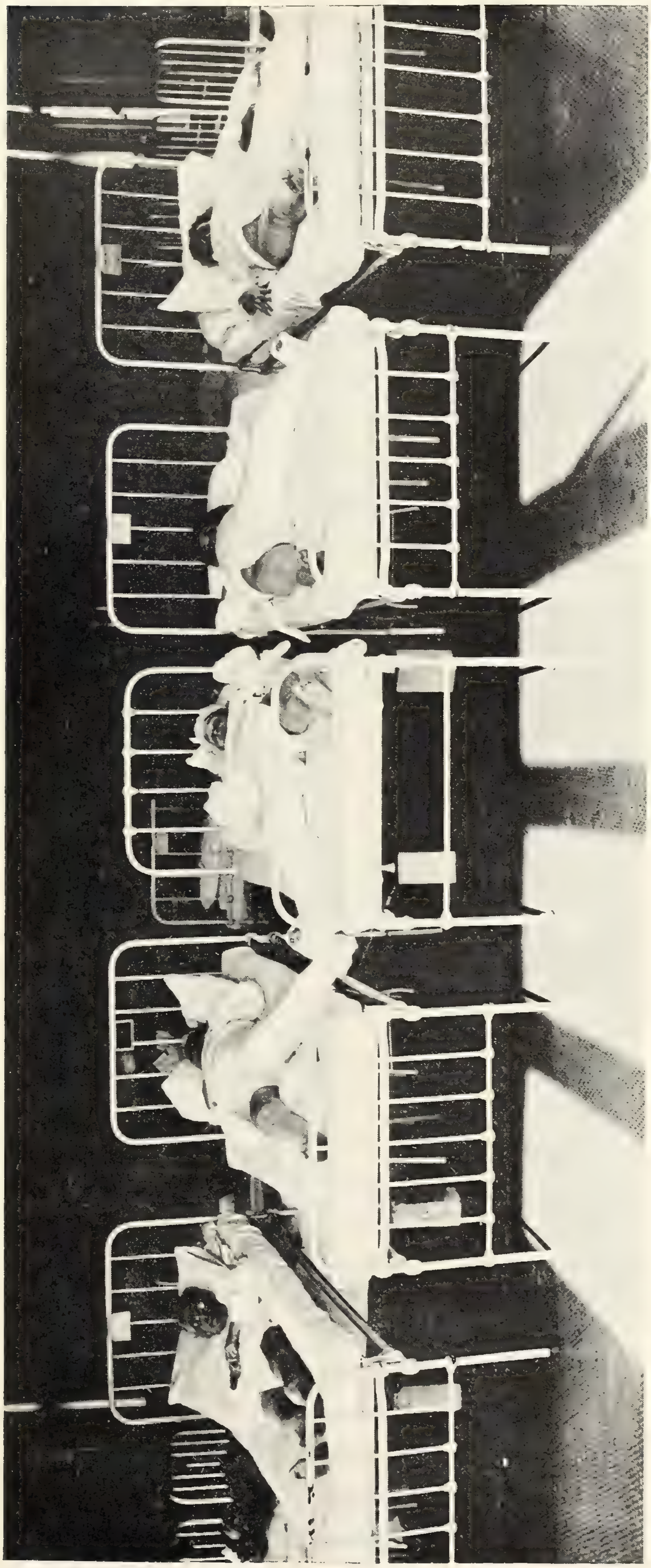


FIG. 435. Five patients under treatment, from one of whom the plaster has been removed for massage and exercise. (Courtesy of Annals of Surgery)

them. Artificial impaction may be mentioned only to complete the list of procedures designed to supplement inadequate external appliances for which there is now no further indication.

In order to avoid misapprehension the distinction between the old and the new system is emphasized — namely: That conventional treatment in design and execution is essentially palliative in character, as exemplified by the indications that have been quoted, the results being determined by the character of the injury rather than by the quality of the treatment. In this section, fracture of the neck of the femur has been considered as a fracture, to be treated in accord with surgical principles, therefore, but one method has been described because it is the only means of making these principles effective. This contrast between negative and positive teaching explains, doubtless, the general impression that the abduction treatment is a hazardous procedure, adapted only to young and vigorous subjects, whereas, in fact, it is the treatment of selection for elderly and aged patients, for no restraint is as complete and depressing as the pain of an unsupported fracture nor as dangerous as the persistent dorsal recumbency enforced by the traction treatment.

Apparently, because of the distinctive name, there seems to be a common misapprehension that the method consists simply in fixing the limb in abduction, whereas, this is what may be termed the third movement in the composition. It may be of advantage, therefore, to again set down the steps of the operation in sequence.

If the surgeon has trained assistants, he stands on the side of the injured hip guiding the trochanter to its proper place but his chief function is to verify the correspondence of the anatomical relations of the two sides before the spica is applied.

1. The limb is drawn directly downward, reducing the shortening and bringing the fragments into the same plane.

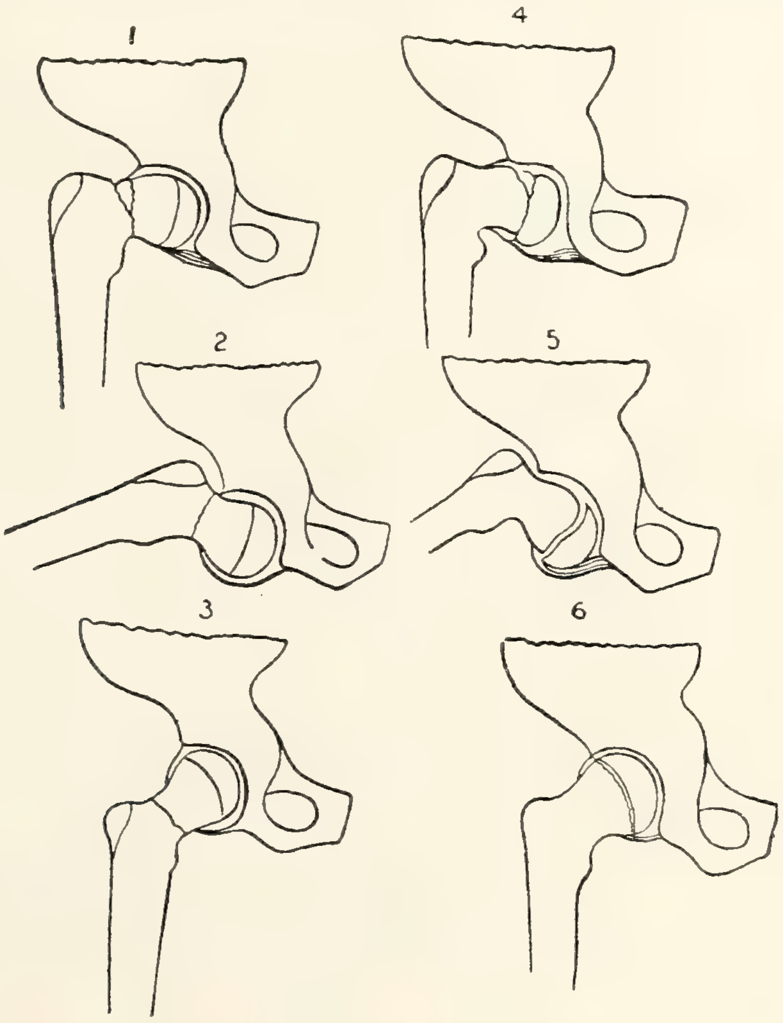
2. The limb is rotated inward because outward rotation, an almost constant symptom of the fracture, indicates that the shaft fragment is turned forward. The fragments are now apposed.

3. Both limbs are then abducted under traction to the full anatomical limit. This forces the fragments into resistant contact and, as it were, locks the fracture. The limb is fully extended because, in addition to the advantages already specified, the fragments are forced forward against the tense anterior wall of the capsule, thus aiding in assuring security. The knee is slightly flexed to relieve tension and the foot is placed at a right angle with the leg to prevent equinus deformity.

Finally, although the object of treatment is bony repair, in some instances, according to statistical reports, fibrous union assures satisfactory function, dependent, it may be assumed, upon close apposition of the fragments and the resistance of the connecting tissue. This outcome should be favored by the abduction treatment as compared to the conventional routine because it assures approximation of the fragments and protection for a much longer period.

FRACTURE OF THE NECK OF THE FEMUR IN CHILDHOOD

Fracture of the neck of the femur in childhood is usually caused by severe injury, often a fall from a height. The fracture is usually incomplete, the neck having been forced downward and backward upon the shaft. The diagnosis should be evident from the shortened limb and the elevated and prominent trochanter. The first indication is reduction of deformity. This in recent cases may be accomplished by traction on the limb and downward pressure on the trochanter aided by what is called natural leverage. For, as the limb is abducted, the depressed neck coming into contact with the upper border of the acetabulum becomes a fixed point to which the shaft is adjusted by abducting the limb and rotating



Original diagrams 1902

FIG. 436. 1, fracture of the neck of the femur; 2, restoration of the normal angle by forcible abduction; 3, the limb in normal position; 4, 5, and 6 illustrate separation of the epiphysis of the head of the femur treated by the same method.

inward. Repair is much more rapid than in older subjects and the children usually walk about while still encased in the spica but a protective splint should be worn for several months to relieve the weakened part from weight-bearing. Unfortunately the diagnosis is not often made at the time of the injury and the patients are not brought for treatment until the fracture has consolidated; the persistent limp and discomfort being mistaken for symptoms of hip disease. In such cases the deformity must be corrected by osteotomy as indicated in the illustrations.

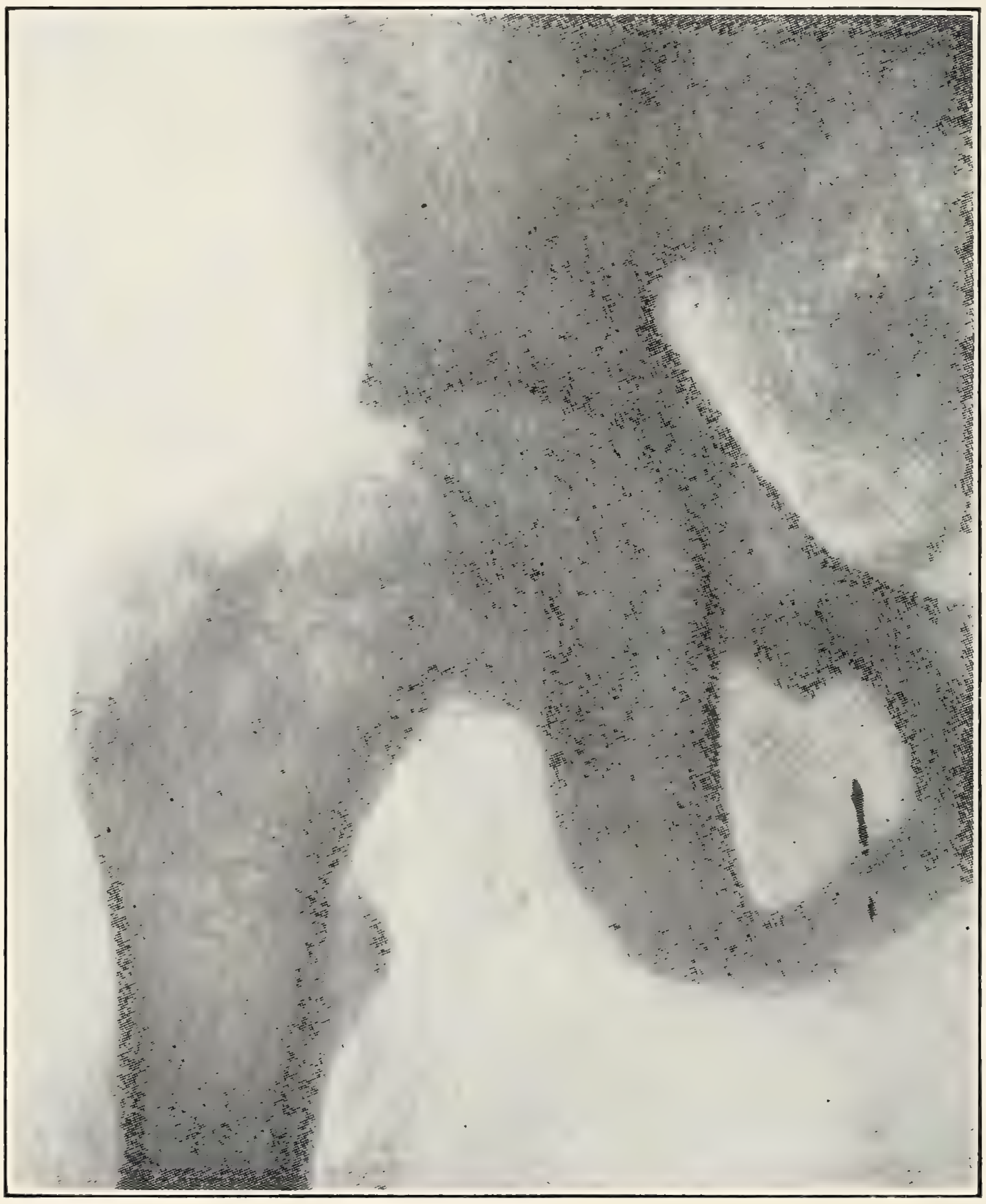


FIG. 437. Epiphyseal fracture in a boy, aged fourteen years, illustrating the progression of the deformity. (Courtesy of Annals of Surgery) See Fig. 438.

EPIPHYSEAL FRACTURES IN ADOLESCENCE

These occur in two forms, the first from direct injury as in violent games. In such cases the diagnosis is usually suggested by the physical signs and confirmed by X-ray examination. The deformity is easily reduced by the abduction method as indicated in the illustrations.

The second type is a gradual progressive form, sometimes called slipping epiphysis, and when the displacement is advanced it is called epiphyseal coxa vara. In many instances the patients are of the fat, overgrown type indicating endocrine disturbance. They are constitutionally predisposed to all forms of postural weakness and to the displacement of this epiphysis rather than others because of the obliquity of its junction with the neck. In patients of this type, as well as in normal subjects, the exciting cause is injury often of a slight character but sufficient to weaken the growing bone at the epiphyseal junction. Then begins a process of gradual displacement of the head backward and downward (Figs. 437, 438). The symptoms are discomfort of the nature of stiffness

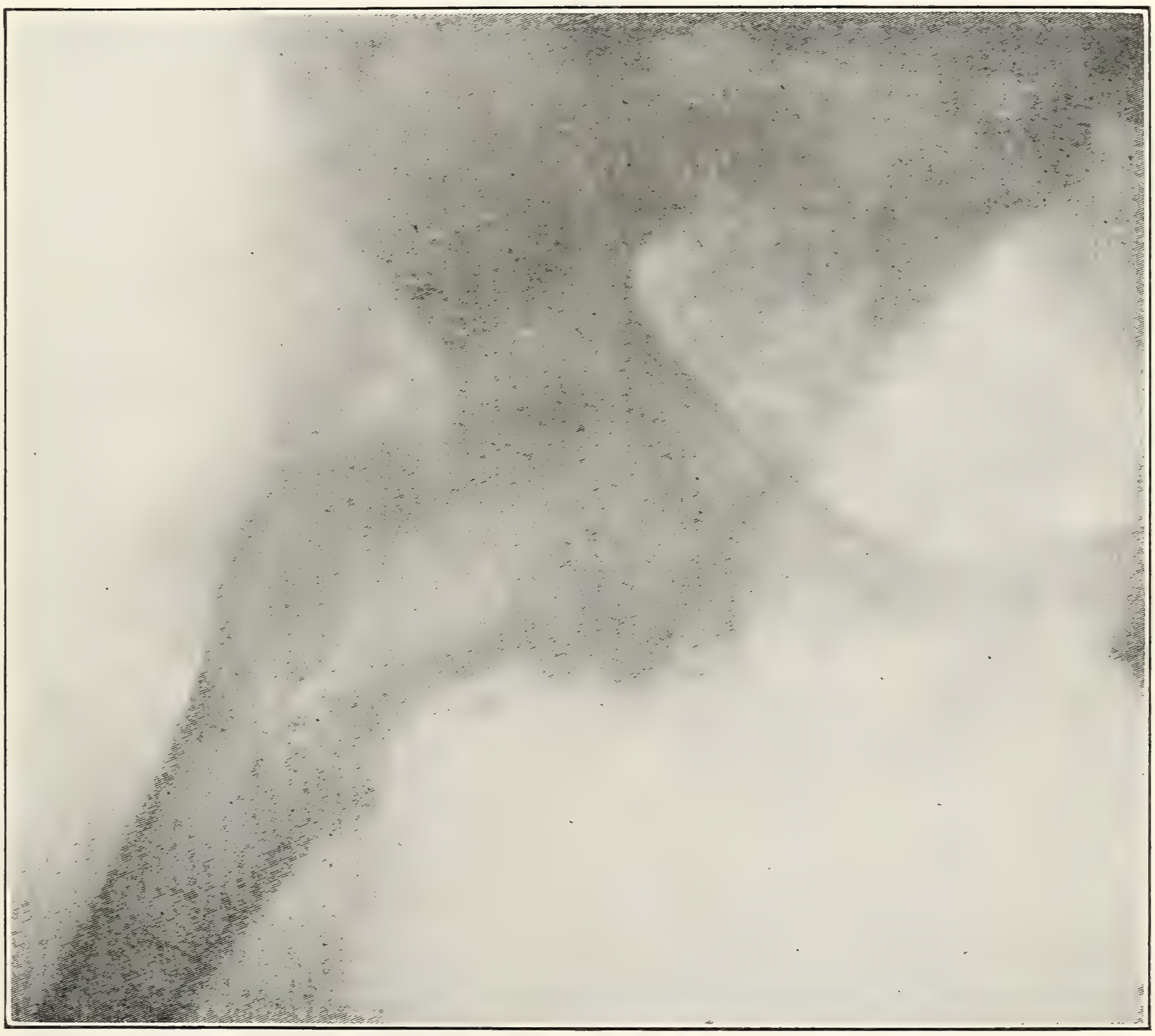
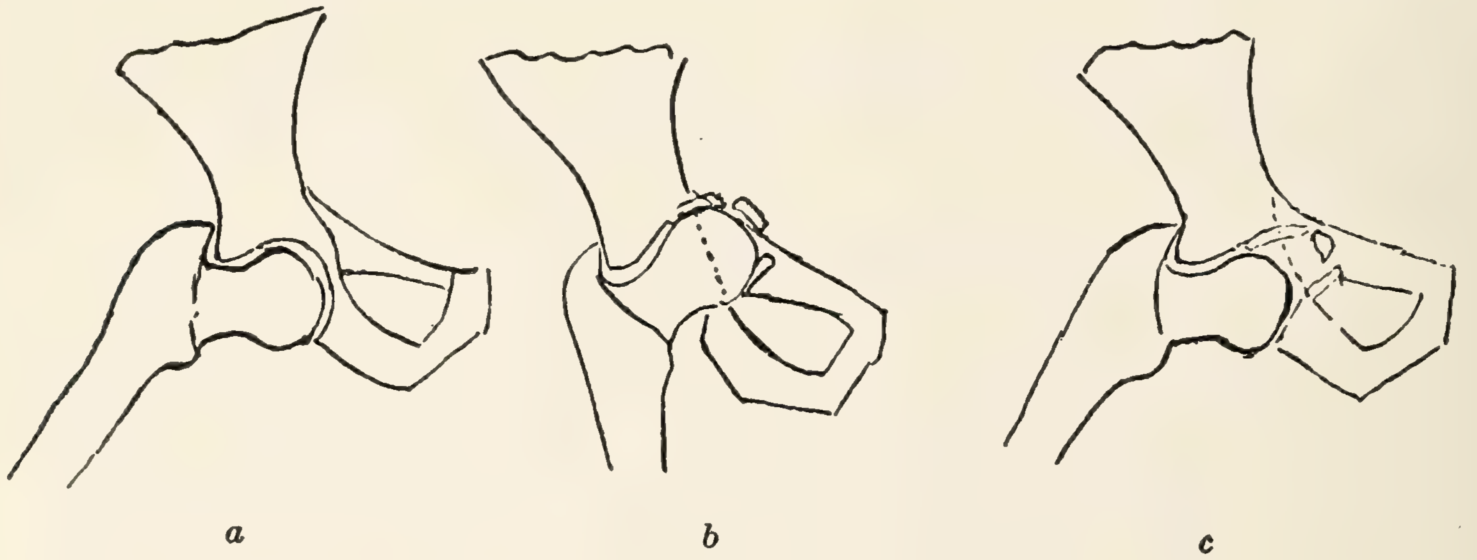


Fig. 438. Epiphyseal Fracture after reduction. Taken through the plaster spica. Contrast with Fig. 437. (Courtesy of Annals of Surgery)

in the joint and limp. The physical signs are outward rotation of the limb and limitation of flexion and abduction. In some instances the



Diagrams illustrating acetabular fracture and displacement and the mechanism of reduction by the abduction method.

FIG. 439, *a*. Contact of the trochanter and pelvis at the limit of normal abduction.
439, *b*. Contact of the trochanter and pelvis in central luxation restricting abduction.
439, *c*. Reduction of the displacement by the abduction method. (Courtesy of Annals of Surgery)

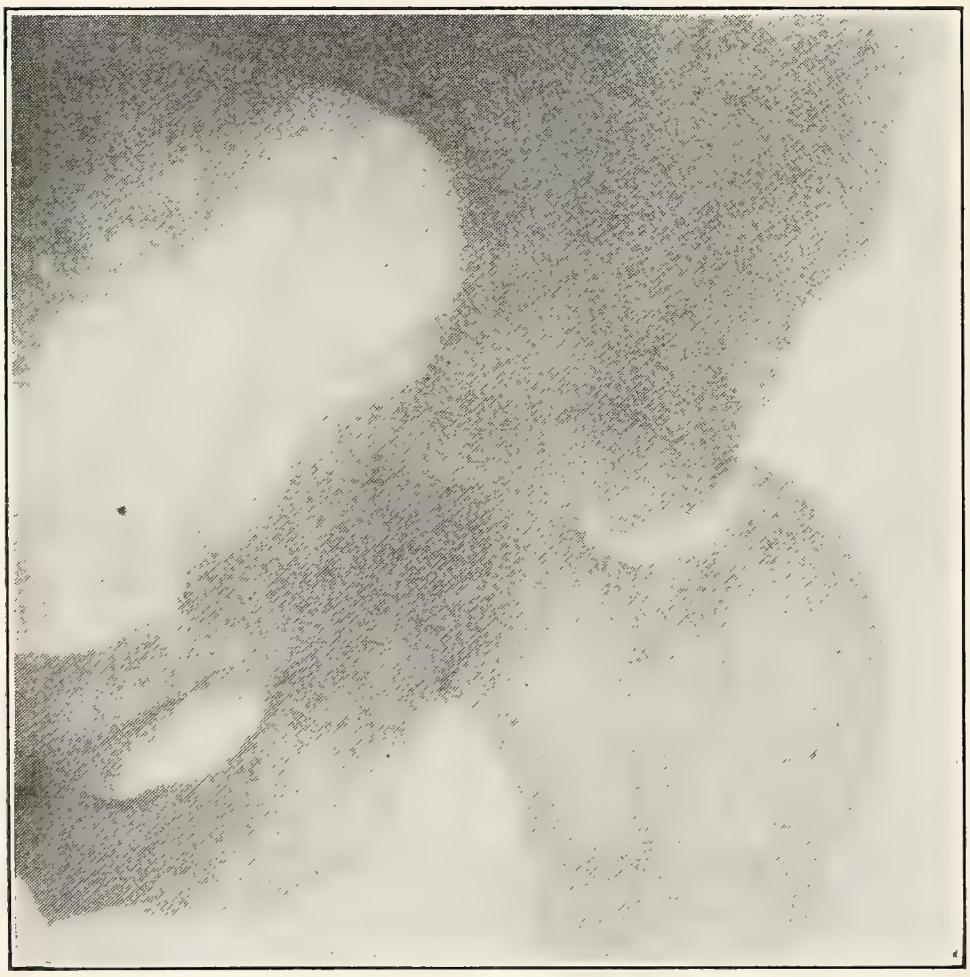


FIG. 440. Central fracture of the acetabulum with penetration of the head of the femur, showing contact of the trochanter and acetabular rim limiting abduction. (Courtesy of Annals of Surgery)

weakened part may give way suddenly and the fracture may become complete but usually the displacement is accompanied by a process of repair, thus the articulating extremity becomes of an irregular shape and joint motion is correspondingly restricted. In many instances, if the condition is of short duration, symmetry may be restored by forcible manipulation of the limb in abduction and inward rotation [1] but in others operative reduction is required. The joint is opened by an antero-lateral incision; a thin chisel is then inserted between the extremity of the neck and the head. When the separation is complete combined leverage of the chisel and abduction and inward rotation of the limb the normal relations are restored.[2]

CENTRAL FRACTURE OF THE ACETABULUM

This as compared with fracture of the neck of the femur is a rare injury. It is usually caused by a direct fall on the trochanter or similar violence, which forces the head of the femur through the floor of the acetabulum. (Fig. 439.)

The symptoms on physical examination are slight shortening of the limb, lessening of the prominence of the trochanter, great limitation of motion, especially in rotation and abduction. The diagnosis is usually made, however, by X-ray examination (Fig. 440).

The primary object of the treatment is to withdraw the head from the pelvis and in most instances can be accomplished only by the abduction method. For since the trochanter is apposed to the upper border of the acetabulum, a contact which under normal conditions could only be approximated by full abduction, one may by forcible abduction, using the trochanter as a fulcrum, withdraw the embedded head.[3]

In a recent case it may then be possible by pressure from within from the rectum or vagina to replace the base of the acetabulum, but in my experience the opportunity for immediate treatment is never offered. After reduction of the displacement the limb is fixed in abduction by a plaster spica until it may be assumed that the reparative changes within the joint will prevent redisplacement (Fig. 441). The after treatment must include regular, methodical, passive abduction to the normal limit until muscular control has been established.

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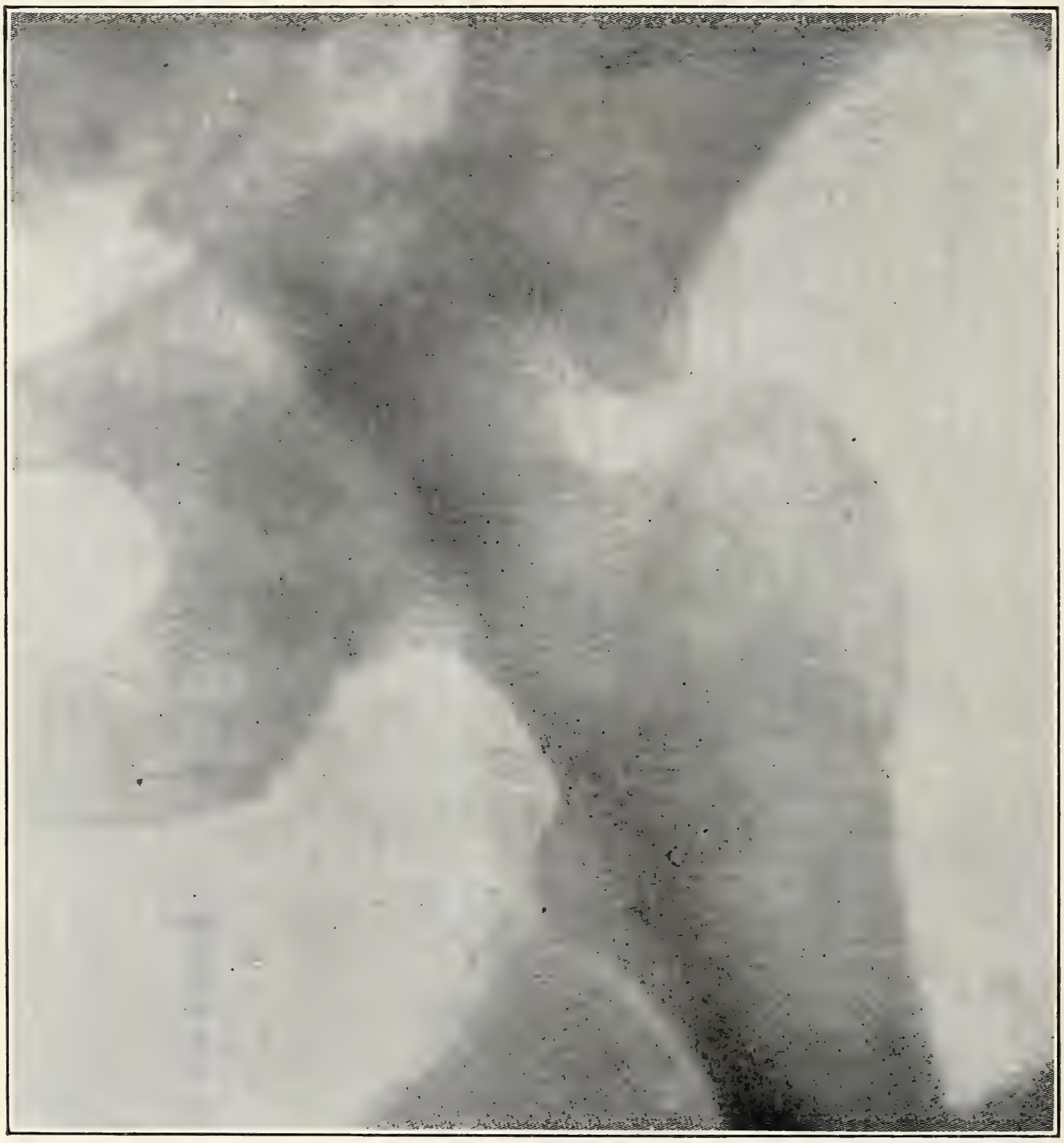
[1] Whitman. Annals of Surgery, November, 1922.
[2] Whitman. N. Y. Med. Record, January, 1909.
[3] Whitman. Annals of Surgery, January, 1920.

UNUNITED FRACTURE OF THE NECK OF THE FEMUR

As has been stated, in a certain proportion of the cases of transcervical, and particularly subcapital fractures, nonunion is inevitable, but since it is impossible to detect these in advance, all patients should be assured the opportunity for repair. If in spite of verified opportunity, as this has been defined, there has been failure of union, the chances are so strongly against success by bone grafting that a more radical procedure is indicated.



Central Fractures of the Acetabulum

FIG. 441. After reduction by the abduction method. Taken through the plaster spica. (Courtesy of Annals of Surgery)

At the present time nonunion of intracapsular fractures under conventional treatment is the rule rather than the exception, and as the capacity for repair has not been tested, bone grafting may be indicated in cases in which the the destructive changes have not progressed sufficiently to interfere with function in the event of repair.

An ununited fracture at the hip is both a disabling and a painful condition, and since the disability is due to the lack of bony resistance in weight-bearing and consequent friction it usually increases rather than lessens with the lapse of time.

In the great majority of cases the restoration of even an approximately normal condition by direct union of the fragments is very doubtful, and operations for this purpose are rarely advisable, since after a period of prolonged invalidism the patient requires above all the assurance of relief of pain and instability in a definite time. These conditions are best met by the reconstruction operation, in which the result, as contrasted with bone grafting or like procedures, is independent of the uncertainties of repair.

THE RECONSTRUCTION OPERATION

In the typical cases of ununited fracture very little of the neck remains and a new articulation must be constructed. This is accomplished by cutting through the base of the trochanter in the line of the neck so that the area thus obtained may serve as a new bearing surface. The head of the femur is removed and the trochanter with its attached muscles is transplanted to the outer side of the shaft thus restoring the leverage of the abductor muscles. This assures the attitude of abduction, and thus the stability of the new articulation, and yet a useful degree of controlled motion is retained. Since this procedure is designed to restore as far as practicable the normal anatomical relations of the joint, it has been called the reconstruction operation.

An incision is made in the shape of a half U, beginning about one inch behind the anterior superior spine, and extending downward and back ward, crossing the femur at a point three inches below the apex of the trochanter. The interval between the tensor vaginae femoris and gluteus medius muscles is exposed; the capsule is opened and the head of the femur is removed.

The anterior margin of the gluteus minimus is followed to its insertion, and at this point with a wide, thin chisel; the base of the trochanter is cut through in an oblique direction corresponding to the angle of the neck, including all its muscular attachments (Fig. 442), and often a part of the capsule. This flap of bone and muscle is turned upward and the upper extremity of the femur, having been somewhat remodeled by cutting away the projections of the posterior intertrochanteric line, is freed from any restraining tissues and is thrust completely within the acetabulum at an angle of about twenty-five degrees of abduction (Figs. 443 and 444).

The trochanter is then drawn downward, as far as its attachments will permit, and sufficient cortex having been removed from the lateral aspect of the femur, the two bare surfaces are apposed, the axis of the trochanter being thereby changed from a direction upward and inward, to outward and upward. In this position it may be secured directly to the

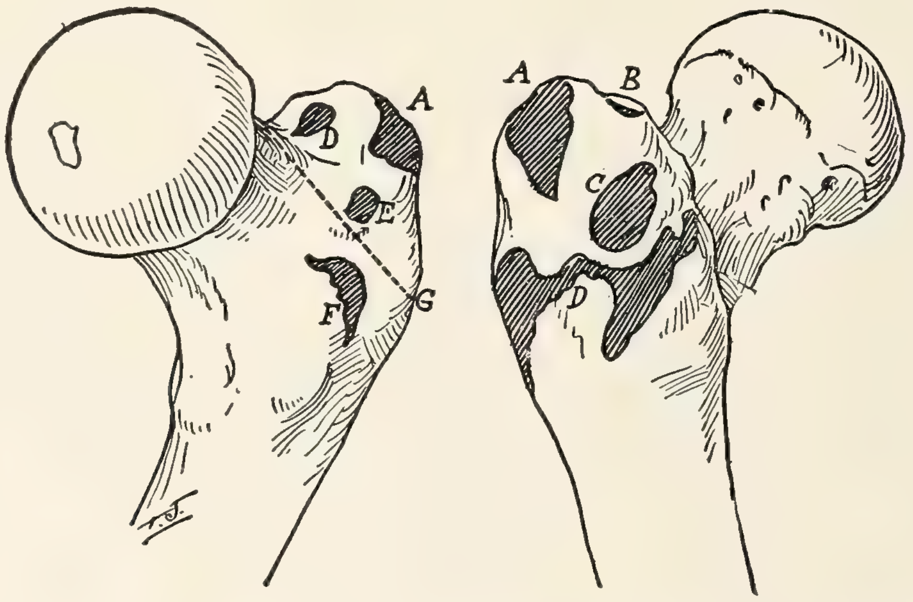
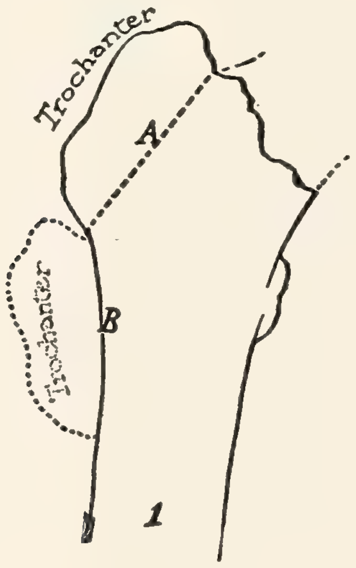


FIG. 442. The muscular attachments of the trochanter. At left, the posterior and internal surface of the trochanter. *a*, Gluteus medius; *d*, obturator internus pyriformis, and gemelli; *e*, obturator externius; *f*, quadratus femoris; *g*, line of section. At right, the anterior and external surface of the trochanter. *a*, Gluteus medius; *b*, pyriformis-obturator internus and gemelli; *c*, gluteus minimus; *d*, vastus. (Courtesy of Surgery, Gynecology and Obstetrics)



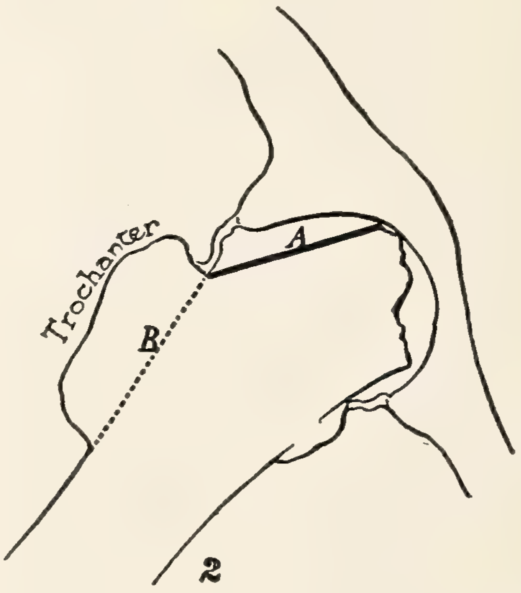


FIG. 443. The reconstruction operation. Figure (at left), the line of section of the trochanter and the point on the shaft to which it is to be transferred. (Courtesy of Surgery, Gynecology and Obstetrics)

FIG. 444. The reconstructed neck. (Courtesy of Surgery, Gynecology and Obstetrics)

femur either by a drill or peg, but usually by kangaroo sutures passed through the muscles above and below. The wound is closed in layers and a long plaster spica is applied, fixing the limb in extension and abduction. When repair has sufficiently advanced, or in about four weeks, this may be replaced by a short spica and the patient is encouraged to bear weight in order to hasten the reconstruction of the articulation by a functional adaptation of the limb to the new conditions. Methodical, manual stretching of the limb in the direction of extension and abduction is of importance and regular physiotherapeutic treatment is of advantage if obtainable.

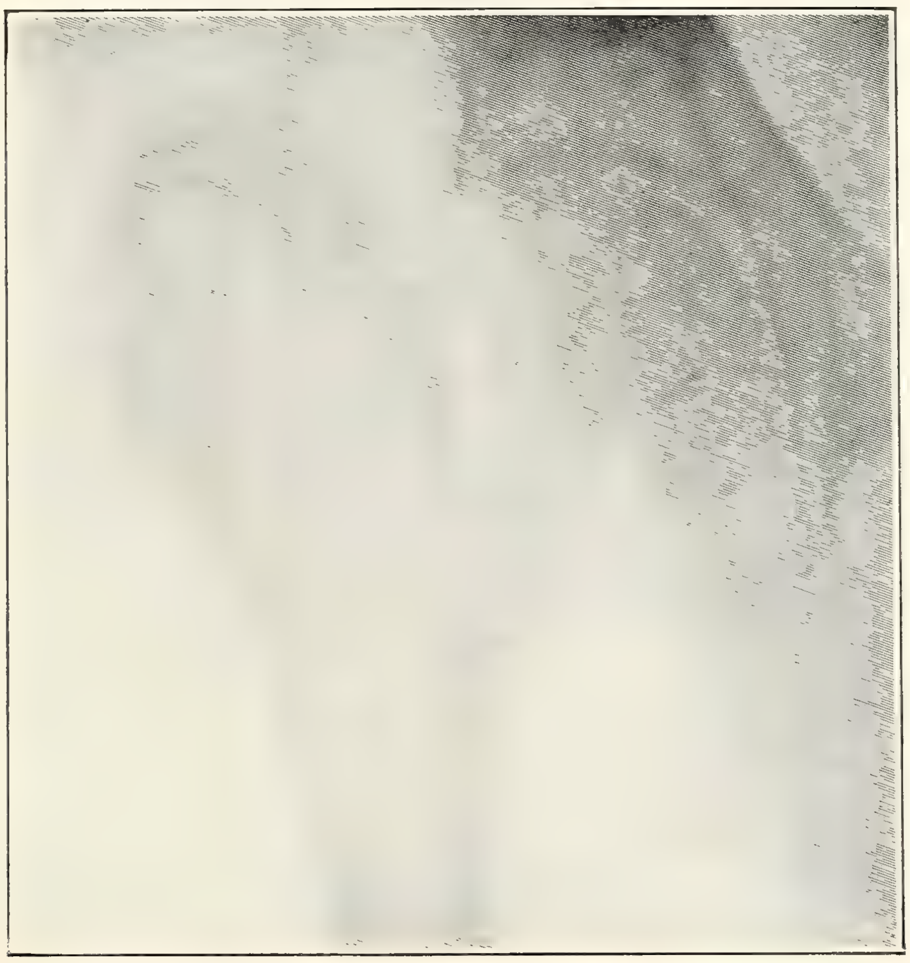


FIG. 445. Before operation, showing complete "absorption" of the neck. (Courtesy of Surgery, Gynecology and Obstetrics)

The results of the operation are usually very satisfactory to the patients since they gain a secure support in walking and thus relief of insecurity and pain incidental to friction. A fair range of motion is assured that enables the patient to sit with comfort and the functional results as far as the limp is concerned will compare very favorably with those of successful bone grafting if the normal components of the joint have been retained (Figs. 445, 446, 447).

THE PEGGING OPERATION

The field for operative treatment of which the object is to restore the normal relations by union of the fragments is now a very restricted one because the outcome is uncertain, and because the functional result in successful cases is often no better than after the reconstruction operation. The operation should be limited to vigorous subjects and to those cases in which a fair proportion of the neck has been preserved and in which it may be assumed, usually because of a history of inefficient treatment, that the capacity for repair has not been thoroughly tested.

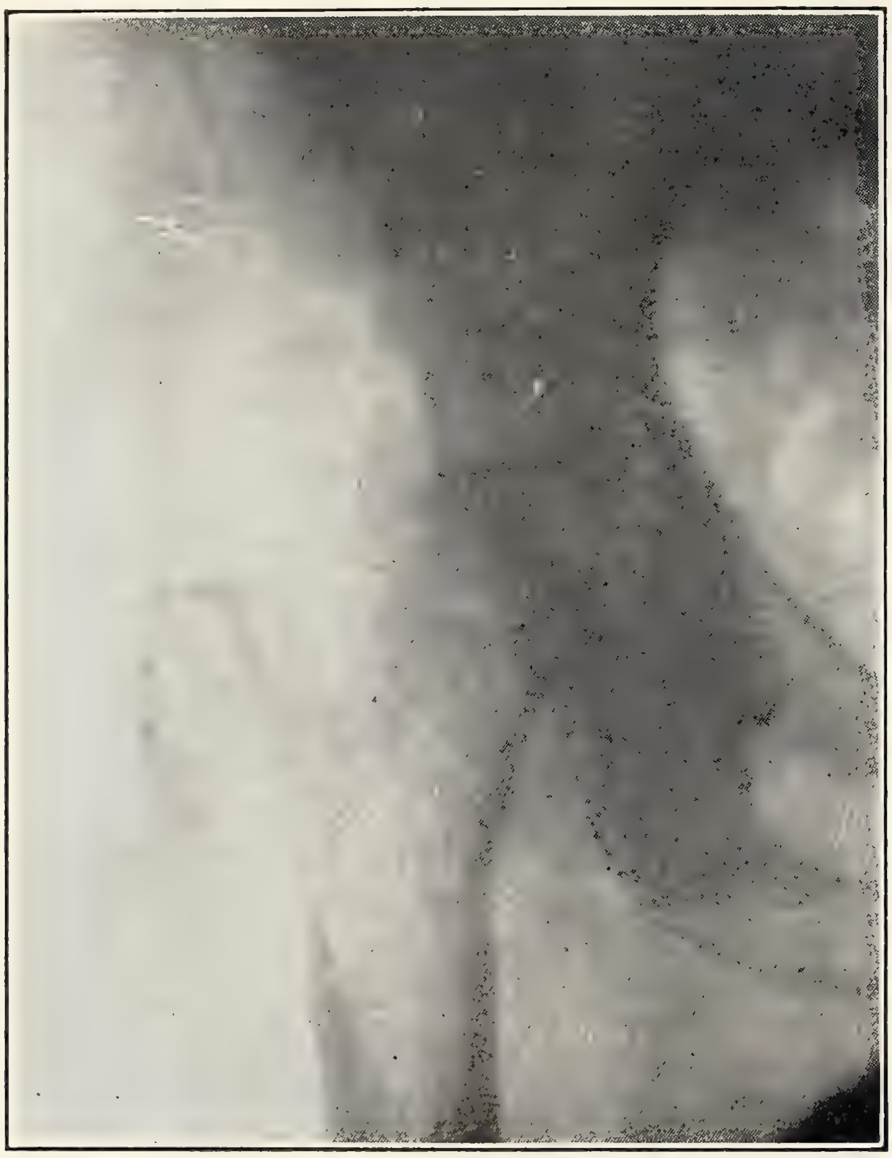


FIG. 446. Showing the reconstructed neck and transplanted trochanter. (Courtesy of Surgery, Gynecology and Obstetrics)

The joint is exposed by an incision between the sartorius and tensor fasciæ femoris muscles. The capsule is opened, exposing the fragments. These are covered with fibrous tissue which must be cut away and the apposing surfaces so shaped as to assure accurate adjustment. An incision is then made on the external surface of the limb, exposing the femur at the base of the trochanter. At this point a drill is pushed through the cortex, following the angle of the neck until it emerges from the center of the distal fragment. The neck and head are then apposed by manual traction on the limb and abduction and the drill forced deeply into the head.

Fixation by this method has been in great degree supplanted by the autogenous bone peg which has the advantage of stimulating repair. This is usually cut from the crest of the tibia and fashioned by a doweling machine into a peg about the thickness of a lead pencil. A hole of corresponding size following the line already described is made, preferably with a motor drill, into which the peg is driven. Some surgeons use a section of the fibula. This has the advantage of strength, but it requires the excavation of a larger and more irregular channel. The wounds are closed and a plaster spica is applied in the degree of abduction that assures opposition of the fragments.

FIG. 447. A transcervical fracture showing complete loss of the neck. A case in which the reconstruction is indicated. (Courtesy of Surgery, Gynecology and Obstetrics)

The after treatment is similar to that already described.

In conclusion, it may be stated again that fracture of the neck of the femur should be considered from the therapeutic standpoint as an entity. In other words, it should be treated like other fractures involving joints, with the aim of restoring function by immediate reduction of deformity and by efficient after care. This point is emphasized because in the past the supposed incapacity for repair of one form of fracture has served as an excuse for the comprehensive neglect of all forms.

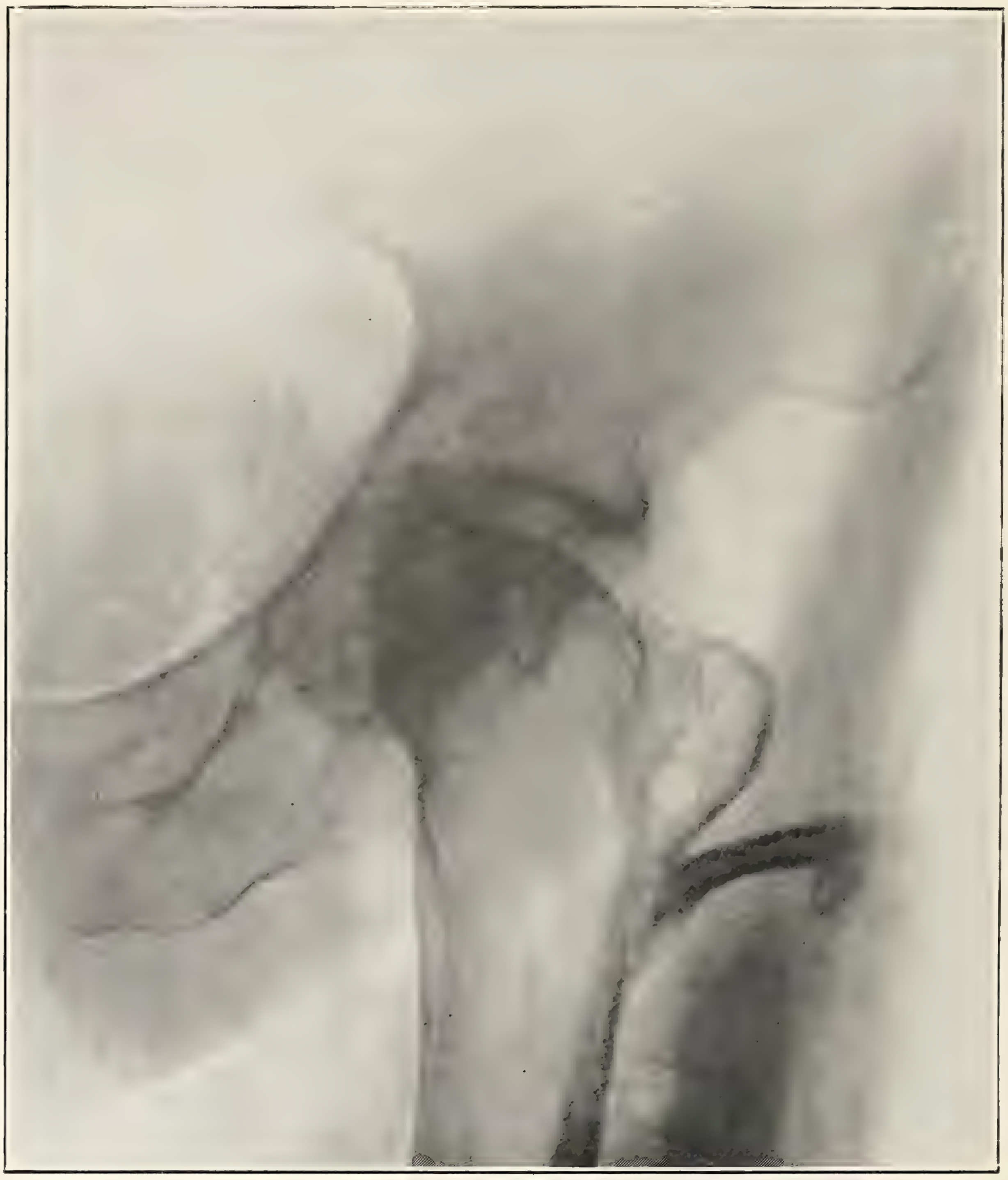


Fig. 448. The Reconstruction Operation for Transcervical Fracture showing the transplanted trochanter and a projecting fragment of cortical bone from the shaft. The security of the reconstructed neck is evident.

The prognosis as regards union for intracapsular fracture is no longer hopeless but simply uncertain, and if in such cases there is failure of repair after verified opportunity, the reconstruction operation offers the only assurance of relief.

THE TREATMENT OF DIABETIC PATIENTS WITH SURGICAL COMPLICATIONS

NELLIS B. FOSTER, M. D.

TABLE OF CONTENTS

Acidosis and Infection 1110
Influence of Infection on Oxidation of Sugar 1112
Water metabolism 1113
The effect of anesthetics 1113
Use of Insulin 1114
Common Surgical Diseases 1118
Gangrene of the Foot 1119
Acidosis simulating acute intra-abdominal disease 1120

THE TREATMENT OF DIABETIC PATIENTS WITH SURGICAL COMPLICATIONS

Nellis B. Foster, M.D.

When a wound is indolent and shows slight tendency to heal the three commonest causes are: syphilis, hypothyrea, and diabetes mellitus. It is well recognized that the absence of glycosuria does not exclude diabetes. After the fifth decade in life it is not rare to observe diabetics with an elevation of the blood sugar to 200 mg. per 100 c.c. of blood but no glycosuria. There is in these cases commonly an elevation of blood pressure above normal and evidence of arterio-sclerosis may be noted by examination of the retina. In many nephritis is easily demonstrated. The explanation for the absence of glycosuria when the blood sugar far exceeds the normal range is not entirely satisfactory; it is commonly believed to be due to nephritis or at least to a change in renal function associated with nephritis and the arterio-sclerotic kidney, hence the terms "high renal threshold" or "decreased renal permeability." The important fact that concerns us here is that diabetes can not be excluded by examination of the urine alone; and a sluggish, gaping wound showing no tendency to heal may be caused by diabetes though there be no sugar in the urine. These wounds ultimately become infected and if the underlying disease be not recognized the patient usually dies. On the other hand, the favorable change following reduction of the blood sugar is often marvelous. It is this indolence in the healing of their wounds which is largely the reason for the reputed tendency of diabetics to infection following operations. In the past this tendency to infection amounted to so great a risk that necessary operations were not attempted. The general attitude of surgeons toward operations on diabetics up to five years ago is well expressed by a quotation from Treves[1]: "Diabetes offers a serious bar to any kind of operation, and injuries involving open wounds, haemorrhage, or damage to blood vessels, are exceedingly grave in the subjects of this disease. A wound in a diabetic patient will probably not heal, while the tissues offer the most favorable soil for the development of putrefactive and pyogenic bacteria. The wound gapes, suppurates and sloughs. Gangrene very readily follows an injury in diabetics and such patients show a terrible proneness to a low form of erysipelas and of spreading cellulitis." In contrast to this almost hopeless outlook for the diabetic who requires surgical aid, are a number of reports published since the advent of insulin dealing with all sorts of diseases demanding extensive operations and prosecuted with a degree of success almost equaling a similar series on non-diabetic subjects. Indeed it is not too much to claim that given a few hours for preparation the risk of an operation to a patient with diabetes is hardly increased at all by the diabetes.

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[1] Treves, Frederick. System of Surgery, 1895, p. 268.

In the last decade before insulin was discovered acidosis was the chief menace to the diabetic subject following an operation. Severe acidosis and coma are usually initiated by infections, mild tonsillitis is a sufficient cause when the predisposition is present. And since the majority of the diseases which require surgical intervention in diabetics are either frank infections, such as carbuncles, or become easily infected in any patient, it is easy to understand why acidosis and coma were so common following operations. Indeed pronounced acidosis may be evident when the patient first comes under observation. In such cases unless insulin be at hand the outlook may be hopeless. Some years ago I found that if the blood sugar were above 350 mg. per 100 c.c. or the CO_2 combining power of the plasma below 40 per cent. operations precipitated coma. This experience was confirmed generally and unless the patient receive insulin the criterion still holds. By an intelligent use of insulin, however, these bars to surgical treatment may be entirely ignored.

Acidosis and Infection. The factors in the production of acidosis following infections in diabetic subjects must be clearly understood in order that suitable measures may be used in treatment. When one thinks of it there seems something peculiar in the fact that the type of diabetic patient usually found in the surgical ward should be prone to acidosis. He is usually fat, hence he can not have had severe diabetes in the past; questioning often elicits that he does not know he has diabetes, that is the disease itself has been so far latent and has caused no symptoms. Nearly half of the patients admitted to New York Hospital on account of surgical complications of diabetes were unaware of their diabetic state, having had no symptoms to prompt them to consult a physician. When any infection develops in the body one of the first responses is fever and this rise in temperature is dependent upon increased heat production. For the production of heat oxidation is necessary; either more food is oxidized, or in its absence, more body tissue. And since appetite fails the body tissues are called upon more and more as the infection progresses. Glycogen stores are quickly exhausted to an irreducible minimum; the organism conserves its protein so long as it can do so, therefore there is an excessive demand on the fat deposits to furnish the necessary heat and energy. These conditions prevail in any disease state attended by fever and loss of appetite. They are not peculiar to the diabetic; the tendency of children suffering from the summer diarrheas to develop grave acidosis is familiar. But the basic reason for acidosis in febrile states is that fat is not completely oxidized to CO_2 and water unless carbohydrate be burned with it — or as the fact used to be stated "fats are burned in the fire of carbohydrate." We know that the oxidation of fats runs smoothly to the butyric acid stage but here unless glucose be available an abnormal path is followed leading to diacetic acid and acetone. A gram of glucose is required for each gram and a half of fat in order for oxidation to progress to the normal products; — water and carbon dioxid. But in the diabetic subject the ordinary tendency of ferbrile states to induce acidosis is aggravated because the tissues have lost the power to burn glucose normally. Even the small amount resulting from catabolism of body protein may be excreted in the urine, and as a result the fat catabolism in febrile states is excessive and acidosis certain. These disturbances in metabolism incident to fever and infection are not sufficiently appreciated by physicians in general and by surgeons in particular. Acidosis is very often nothing more than a carbohydrate starvation. The amount of glucose required for correction of the body chemistry is considerable, never less than 50 grams, often 100 grams, and of course the supply must be continued until the febrile state is ended. In order to gain a better insight into the abnormal physiology accompanying fever the following observation was carried out. The basal metabolism of a patient before operation was found to indicate that the heat production amounted to 1664 calories for 24 hours. The day after operation there was the usual febrile reaction, the temperature rising to 102° F. and the metabolism indicated a heat production of 2163 calories. The patient was taking no food and the question of interest was the source of energy for heat. The respiratory quotient was under one which signifies that very little, if any, glucose was being burned. A complete twenty-four hour collection of urine for this day contained 10.8 gm. of nitrogen, equivalent to 67.5 gm. of protein ($10.8 \times 6.25 = 67.5$). This protein should yield 270 calories ($67.5 \times 4 = 270$). Since only negligible amounts of glucose were utilized as was indicated by the respiratory quotient and the metabolism of protein yielded but 270 calories then about 1800 calories must have come from fat ($2163 - 270 = 1983$). The combustion of a gram of fat yields 9 calories, hence 200 grams of fat were used from the body to yield the 1800 calories. A gram of glucose is required for each 1.5 grams of fat if oxidation is to be complete and no ketones formed, and in the above case about 130 grams of glucose would have been needed during the day. The major supply was, in fact, the glucose derivable from protein, only 39 grams (67.5 × 58% = 39.1), with possibly a little from depleted glycogen stores. Instead of a normal ratio of about one gram of glucose for each gram of fat the oxidation in the tissues was proceeding in a ratio of 39 gm. glucose to 200 grams of fat; a ratio of 1 : 5. This explains the presence of ketone bodies in the urine and the evidence of mild acidosis in the blood plasma which were noted during the period of observation. This state of affairs prevails with every patient who has fever and who is not taking a sufficient amount of food; it prevails during the first few days after operations because of the post-operative pyrexia and the inability of the patient to take food; if the fever be high the tendency to acidosis is increased because each degree of rise of temperature causes a rise of metabolism of ten per cent. In diabetics this febrile, glucose-starvation acidosis is enhanced on account of the failure of the diabetic tissues to utilize the glucose which is available.

INFLUENCE OF INFECTION ON OXIDATION OF SUGAR

Any infection increases the severity of diabetes. It is well known that the severity of glycosuria and the blood sugar respond unfavorably even with slight infections such as a transient coryza. So many of the complications of diabetes which require surgical intervention are infections that this fact is important. By increasing the severity of the diabetes, that is to say by decreasing the power of the organism to utilize carbohydrate, not only is the tendency to acidosis increased but the reparative reaction in injured tissues is lowered. The immediate more grave effect is of course the acidosis. Coma is often brought on by such infections as tonsillitis, otitis media, and neglected infected wounds requiring drainage. The diabetic who contracts an infection has started on the road to coma. Formerly we were helpless when confronted with some of these cases. With the aid of insulin now, however, the obstacles are largely overcome and but very few patients are lost. It is astonishing that a patient during the height of a surgical infection may require enormous doses of two hundred units of insulin daily for a period, yet a month later when the wound is healed be able to take an adequate diet without the help of insulin and still preserve a satisfactory blood sugar and no glycosuria. The great majority of the cases of diabetes are mild; severity of the disease is usually transient and due commonly to infections.

Water metabolism. The results of disturbances in the water content of the tissues is seldom considered unless they are obvious. Yet these results are very definite and most important when life hangs in the balance. Moderate dehydration induces a rise of temperature and a severe dehydration may be produced in animals resulting in hyperpyrexia. The importance of dehydrations of the tissues to the present discussion is its relation to acidosis. Any swing in the reaction of the blood toward decreased alkalinity is accompanied by a loss of water from the tissues and it was noted[1] years ago that in severe acidosis the red blood cell count is elevated, indicating a state of anhydremia. There are several factors which tend to produce tissue dehydration in the diabetic subject. Usually he voids more urine than normal and compensates for this by drinking more water. Fever and infection tend to increase the water output. But the drowsy state resulting from fever is apt to decrease the amount of fluids the patient drinks; as he grows sicker he drinks less and less till coma supervenes. Often, too, there is nausea, even vomiting, which thwart any attempt to relieve thirst. The dehydrated state of the diabetic patient with infection and acidosis is equalled only by that of a child suffering from cholera nostras. The appearance of the tongue and pharynx are characteristic.

The effect of anesthetics. There are two primary effects of general anesthesia, (*a*) decrease in the utilization of glucose, (*b*) production of acidosis. Neither of these effects is peculiar to the diabetic, in him the common result is only exaggerated. Every surgeon has noted transient glycosuria following anesthesia in persons who had no sign or symptom of diabetes. The reason for this is that anesthetics, especially ether, induce a rise in the level of the blood sugar; this is roughly proportionate to the length of the period of anesthesia and to the amount of anesthetic used. Before anesthesia the blood sugar may be only .06 — .09 gm. per 100 c.c., and at the end of an hour of narcosis rise to .17 or .18 gm. This is just over the normal threshold level of the kidneys and glycosuria results.

The influence of an anesthetic on the alkaline reserve of the tissues is more important. It was clearly shown by Van Slyke that either at once or in a short time after the anesthesia is begun a true acidosis occurs with increase of the hydrogen-ion concentration of the blood and fall of the alkaline reserve. This acidosis is due either to introduction of acid into the blood or to withdrawal of base from it.[2] This state of affairs may be of grave importance in many surgical operations, it always is in operations on patients with thyrotoxicosis and with diabetes. It is not possible to escape this menace entirely if general anesthesia be employed but acidosis is less with nitrous acid and oxygen than with ether and least of all with ethylene. But so much depends upon the experience and skill of the anesthetist that no general rules are possible.

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From what has been said of the unavoidable effects of general anesthetics it is evident that local anesthesia is preferable whenever practicable, and in experienced hands this is now a very wide range.

Use of Insulin. The foregoing discussion of the physiology of diabetes and the effect upon it of some factors important in surgery is indispensable to any clear understanding of the concrete problems presented by sick patients. For the diabetic subject requiring surgical treatment the constant menace is acidosis. An appreciation of this danger and an insight into its mode of production is not compensated for by the highest degree of operative skill. But if the problem is comprehended and some knowledge of methods of treatment diligently employed the results are most satisfactory. With the aid of insulin we may proceed with confidence where a few years ago no operation would have been ventured. But insulin must be used with diligence and intelligence. It is not sufficient to direct that ten or twenty units of insulin be given two or three times a day and then forget it. The dose may be hopelessly inadequate or after a few days it may be excessive and produce shock. From the point of view of the surgeon the use of insulin has a different aspect than to the physician who is balancing the dose to a standard diet in order to control glycosuria. The surgeon is treating an emergency, conditions are changing constantly, there is no diet. The patient takes but little food, takes it irregularly, and may vomit what he takes. The result of these variables is glycosuria at times, none at others, but ketonuria constantly. Under these conditions it is not indicated to stop insulin when sugar vanishes from the urine but to give the patient glucose. If it can be given by mouth, lemonade, orange juice, and fruit juices meet the need; if glucose can not be given by mouth then 20 grams of 50 per cent. glucose should be injected into a vein every two or three hours until the last trace of acetone vanishes from the urine. The dose of insulin needed in some cases where a neglected infection has thoroughly intoxicated the patient and there is clinical acidosis may be enormous; four or five hundred units during twenty-four hours. Under these conditions a patient must be under constant observation, not only to ward off insulin shock by timely glucose injections but to determine what each succeeding dose of insulin should be. The urine should be tested for glucose every hour, at least every two hours; if sugar is present insulin should be given, the dose being regulated by the degree of glycosuria; if there be no glycosuria, give glucose and continue this until ketones vanish from the urine and the patient is out of danger. Quantitative estimations of sugar in the urine are not necessary; all that one needs to know is whether there is much sugar, little, or none; which is easily estimated by the reduction of the copper in Fehling's or Benedict's solution. This test and the reaction of a sample of urine to ferric chlorid solution indicating the amount of diacetic acid can be done at the bedside.

In outline this is the general method of treating diabetic acidosis, the crucial factor in many complications demanding surgical intervention. If one can handle acidosis effectively the patient can be tided over the most critical period and details relating to the mere diabetic state and its bearing on the healing of the wound may then be considered later. *Surgical patients do not die of diabetes; they die of acidosis.*

The details of the treatment are best described by an illustrative case. The patient was a woman 51 years of age, rather stout in spite of diabetes of some years' duration. She had been under her physician's care for a week on account of acute cholecystitis, and a consulting surgeon had advised operation. During the night of February 7 the patient's condition had suddenly become worse and it was suspected that the inflammation was suppurative. On the morning of the eighth, operation was considered imperative and the patient was taken to a private hospital. Examination of the blood disclosed a marked degree of acidosis and at this time the patient came under my observation. There was no time for any adequate preparation for operation and attention was directed solely to the control of acidosis. Sixty units of insulin were given subcutaneously and forty intravenously. The elevated blood sugar and glycosuria indicated no immediate need of glucose, but the appearance of the skin, tongue and pharynx did indicate a serious need of water. The operation was begun about eleven and was completed before one, a distended gall bladder filled with stones and pus being removed. During the operation a liter of physiological salt solution was given by hypodermoclysis under the breasts and in the lower axillae. This was repeated during the afternoon and supplemented by instillations of tap water by rectum. Directly after the operation 20 grams of glucose were injected into a vein and 20 units of insulin given. The urine was tested every two hours during the 24 hours following operation and insulin and glucose given as indicated; the glucose being given intravenously. The accompanying chart shows the times and amounts of insulin and glucose given; in all 250 units of insulin and 160 grams of glucose. The subsidance of the ketonuria and the rapid rise of the CO_2 combining power of the blood are specially notable. The next step was to allow small amounts of orange juice by mouth, and on the third day after operation, milk, gruel, and broth. Insulin was given every four hours in variable dosage depending on the intensity of the glycosuria, but no attempt was made to keep the urine free of glucose until the following week when the patient was considered out of danger; the sole aim in the beginning being to prevent serious acidosis. This patient was alive in June 1926 and in good health in spite of diabetes.

Chart No. 1. Showing Summary of Treatment of Case

Date		Urine					Blood		Diet				Insulin in Units
		Volume	Sugar %	Grams Sugar	Acet	Diac	Glucose	Co_2	C.	P.	F.	Cals.	
2/8/24	11 A.M.		6.1		+++	++	660	31					60 sub-Q 40 Intra-Venous
	1 P.M.		+++		+++	++			#20	0	0		20 sub-Q
	3 "		+++		+++	+++			20	0	0		40 " "
	5 "		1.8		+++	+++			40	0	0		none.
	7 "		1.9		+++	++			0	0	0		40 sub-Q.
	9 "		1.1		++	+	320	56	0	0	0		none.
	11.30		0.7		++	+			20	0	0		20 sub-Q.
2/9/24	2 A.M.		tr.		+	0			20	0	0		none.
	4 "		tr.		+	0			0	0	0		10 sub-Q.
	6 "		+		+	0			20	0	0		none.
	9 "		0		+	0			0	0	0		"
	11 "		tr.		+	0	174	58	20	0	0		20 sub-Q.

glucose, intra-venous,
Total glucose, 160 gram, insulin 250 units, in 24 hours.

Until the last few years cases like the one reported invariably resulted fatally but there are now reported in the literature many instances of successful surgical treatment under most exacting conditions. The important facts constantly to be borne in mind are that acidosis can not be controlled unless glucose is available, insulin alone is often insufficient; glycosuria is significant only as an indicator for the dosage of insulin; dehydration of the tissues and anhydremia must be corrected by giving water.

When a day or two is available for the preparation of a patient for operation the task is much easier and a more satisfactory condition attainable. Sometimes all that is necessary is to prescribe a suitable diet, the glycosuria vanishing promptly and the blood sugar subsiding to 150–160 mg. per 100 c.c. For diabetics requiring surgery no diet is as easily handled as milk. Milk is the easiest food to measure, its chemical composition varies less than other foods, hence the total food taken by the patient can be readily computed even though more milk be taken one day than another. Patients are usually content with a diet of 1500 c.c. of milk daily, if they are sick they are satisfied with less. Average milk contains about 3.5 per cent. protein, 3.5 – 4. per cent. fat and 5 per cent. sugar; 1500 c.c. of milk would be equivalent then to 52. g. protein, 52 – 55 g. fat, and 75 g. carbohydrate, and about 1000 calories. This diet is an ideal one with which to commence treatment of any case of diabetes, surgical or otherwise. If with such a diet the glycosuria does not rapidly vanish, one would use insulin to hasten this end. In hospital cases where time is always pressing (and probably with a majority of private patients too) insulin is now used for a period to hasten an end which could be attained without it, but not so quickly and easily. The best example of this type of surgical case in which there is no emergency but with the necessity of having the patient in the best possible condition for operation is diabetic gangrene. The diabetes in these cases is always of the mild chronic type of years' duration, and unless there be secondary infection there is no acidosis. The risk of amputation depends upon the general state of the patient, the extent of arterio-sclerosis, always present, and often involving the coronary arteries, and upon the acidosis secondary to an anesthetic and infection of the stump. Acidosis can be prevented and when the blood sugar is low infection is less apt to develop in the wound. The following case is an example of gangrene of the foot in a diabetic subject. Radiographs demonstrated calcification of the arteries of the leg and thigh and amputation at the middle of the thigh was considered the correct procedure. Before treatment was commenced the blood sugar was elevated and there was considerable sugar in the urine. There was an immediate response to a diet of 1500 c.c. of milk and this was hastened from day to day by increasing doses of insulin until the blood sugar was reduced to a safe level. On the day of operation only orange juice was given. The anesthetic was gas and oxygen with a very little ether. Six days after operation milk was abandoned and a measured diet substituted. Insulin could be gradually decreased and later dispensed with, the blood sugar remaining low. It was possible for this patient to use a diet of 2400 calories before he left the hospital without glycosuria or hyperglycemia. (Chart 2.)

Cases of this type illustrate very well the necessity of attention to the hyperglycemia, which is second in importance only to acidosis from the surgeon's point of view. Wounds almost always show delay in healing so long as the blood sugar is high; infection then sooner or later is inevitable. This consideration is of moment not only in cases of amputation when the circulation is at best impaired but also applies to wounds in general. The older patients, particularly those who have had diabetes for years, show a high renal threshold, probably due to renal sclerosis since vascular hypertension is so common. The normal person will have sugar in the urine so soon as the blood sugar rises over 170–180 mg. per 100 c.c. It is not rare to note in cases of diabetes of long duration an absence of glycosuria when the blood sugar is over 250 mg. per 100 c.c. These are the cases we hear about as cured of diabetes. Often it is difficult to reduce the blood sugar by diet alone and when there is an infection with fever it may be impossible. Insulin is indicated at these times quite as much as when there is glycosuria. Attempts to meet the situation by sharp reduction in diet or by periods of starvation are very apt to induce acidosis if it is not already present. In several cases of diabetic coma in my series the critical state was the logical outcome of fasting a diabetic patient suffering from a progressing infection.

DIABETES CHART NO. 2

Date	URINE						BLOOD		DIET				Insulin
		Volume	%	Grams Sugar	Acet	Diac.	Glucose	CO_2	C.	P.	F.	Cals.	
3/7/25			++		+	0	360	58	?	?	?		none.
3/8		1755	1.3	22.8	+	0			75	50	55	995	none.
3/9			+		+	0			"	"	"		5 units q. 4 h.
3/10			+		0	0			"	"	"		10 units t. i. d.
3/11			tr.		0	0			"	"	"		15 " t. i. d.
3/12			tr.		0	0	.230		"	"	"		25 "a.m.&p.m.
3/14			0		0	0			"	"	"		25 "a.m.&p.m.
3/17			0		0	0	.140	61	"	"	"		25 " " "
3/18	opera	tion.	0		0	0			†50(	ora	nge j	uice)†	25 " " "
3/19			0		+	+	.170	48	85	30	40		30 " " "
3/20			0		0	0			75	50	55		20 " " "
3/21			0		0	0	110	63	75	50	55		20 " " "
3/22			0		0	0			"	"	"		15 " " "
3/25			0		0	0			‡75	60	80	‡1260	10 " " "
3/27			0		0	0	108		"	"	"		10 " " "
4/1			0		0	0	112		80	70	100	1500	none.

† no milk, only orange juice.
‡ milk diet stopped, regular measured diet.

Common surgical diseases. Carbuncles are so common in diabetes and may lead to such critical conditions if improperly treated that they merit special attention. When there is a diabetic etiology it is possible to excise a carbuncle and secure healing. But usually this method can not be considered on account of the extent of the infection, the problem then is to secure the maximum degree of drainage with a minimal operation. These patients are often very sick, with high fever, intoxicated alike from infection and acidosis, and in no condition to endure an operation. We have found that cross incisions extending out to the margin of induration and deep enough to reach through the infected area constitute the best initial operation. This can be done with gas anesthesia and causes no shock. Drainage is secured and the tension in the tissues which causes so much pain is relieved. Wet compresses are preferable to dry dressings; they allay inflammation and the moisture helps drainage. There is a great deal of sloughing from these wounds and need from day to day of removing necrotic tissue and opening pockets for drainage. It is our impression that healing of these wounds is promoted by exposure to direct sunlight or to the rays of the quartz lamp. The general treatment is that outlined in the preceding remarks.

Gangrene of the Foot. Gangrene of the foot is a menace to all the older subjects of diabetes. In patients past fifty years of age there is usually enough lime in the arteries of the legs to produce a shadow in a radiograph; in some the arteries seem as dense as small bones. When gangrene results from the occlusion of these arteries it is not different from arterio-sclerotic gangrene in general and the limb must be sacrificed. The questions for decision are when to amputate the leg, and the site of amputation. There is no emergency in these cases, a day or two at least is always available for the preparation of the patient. The blood sugar should be reduced to 150 mg. and if the patient is exhausted by pain and loss of sleep, rest and recuperation secured by morphine promotes the rapidity of recovery. During the period of preparation of the patient the affected limb should be protected from the weight of the bed clothes by means of a cradle. Dry heat is helpful and easily secured by attaching an electric bulb to the cradle.

Sometimes it is difficult to decide how much of the limb to sacrifice. One sees instances of spontaneous amputation of the terminal joints of toes, which indicates that very conservative measures may occasionally be successful. On the other hand when the whole foot is involved or the foot and ankle, high amputation is unavoidable. Experience indicates that amputations below the knee are so often followed by delayed healing and infection that mid-thigh is actually a more conservative site.

There is another type of gangrene more peculiar to the diabetic subject since it is not immediately due to arterio-sclerotic changes in the blood vessels but to infection. This type of gangrene is observed in younger patients than the arterio-sclerotic type, the vessels do not show severe degrees of thickening, indeed they may be almost normal. In the beginning there is some slight injury to the skin, a cut, or fissure between the toes, or injury to a corn, or toe nail. This wound becomes infected, the infection extends along fascial planes and not infrequently involves the bones. The wounds are sluggish, soggy with necrotic tissue, and in areas where the circulation is obstructed, discolored. Osteomyelitis is frequently the ultimate result and pieces of necrotic bone are from time to time discharged from the wounds. When neglected too long a general bacterial infection develops, resulting in death; but it has long been a cause of astonishment to me how long this logical sequence may be delayed.

The opinion has been advanced that the only proper methods of treatment of these cases is early amputation; that unless the limb be sacrificed death is inevitable. While it is probably true that amputation well above the infected area is the easier way of solving the problem, and in some cases becomes absolutely necessary to save life; nevertheless to apply this doctrine in every case will sacrifice some limbs that might have been saved. A decade ago it was demonstrated that conservative surgery, careful attention to the diabetic state and patience will effect some remarkable results. In a report of a series treated by Adrian Lambert and the writer,[1] Case III in that report, to which the above remarks would apply, made a good recovery, hunted and fished for ten years and finally died of heart disease. Now-a-days with insulin conditions are easier of control and results better.

The general principles of treatment are easily outlined. As with any other extensive suppurative process the first indication is free drainage; this may involve several deep incisions. Then it can not be stated too emphatically that it is useless to expect a normal reparative reaction in the tissues until the blood sugar is reduced to approximately a normal range.

Acidosis simulating acute intra-abdominal disease. Severe diabetic acidosis is usually ushered in by nausea, often by vomiting, and occasionally by severe abdominal pain. There is sometimes a board-like rigidity of the abdomen which in association with pain, nausea, and vomiting may be very difficult to distinguish from early peritonitis. Unnecessary operations have been done on cases of this type, and I have known of several instances when operations were narrowly avoided. Not every case of grave acidosis presents these symptoms, but in some instances they are so pronounced that the picture of appendicitis or rupture of a viscus is perfectly simulated. At this stage of acidosis the pulse is usually rapid and there may be a slight fever but the temperature tends to fall and become subnormal if coma develop. The chief essential for the correct interpretation of these misleading signs is knowledge that the syndrome may occur. Finding sugar in the urine of a patient suspected of being a case of appendicitis, or of perforated ulcer should lead one to investigate the possibility of acidosis and if this be present the operative interference should be delayed until the acidosis abates. The alarming signs are then apt to have disappeared. Although an unnecessary surgical exploration on a diabetic subject is not to-day the catastrophe that it once was it remains quite as humiliating.

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CLAVICLE

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CLAVICLE

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TABLE OF CONTENTS

Fractures of the clavicle 1124
  Etiology 1128
  Diagnosis 1129
  Roentgen-ray examination 1130
  Complications 1131
  Treatment 1132
  Summary 1144
    Epiphyseal injuries 1144
Dislocations of the clavicle 1145
  Dislocation of the acromio-clavicular joint 1145
  Reduction 1147
    Upward dislocations 1147
    Forward dislocations. 1147
    Subacromial dislocation 1147
    Subcoracoid dislocation 1147
  Immobilization 1147
    Dislocations of the sternal end 1149
    Dislocation of both ends of the clavicle 1149
    Bilateral dislocation of both clavicles 1149
  Operative reduction 1150
Osteomyelitis 1150
  Tuberculous osteomyelitis 1150
  Syphilitic gumma and yaws 1150
  Rudimentary or absence of clavicle 1151
  Tumors of the clavicle 1151
  Treatment of malignancy of the clavicle 1153
Excision and resection of the clavicle 1153
  Method of operation 1154

FRACTURES OF THE CLAVICLE

THE clavicle is one of the most frequently broken bones in the body. Statistics show that from 5 to 10 per cent. of all fractures occur in the clavicle. Factors that contribute to this frequency are chiefly concerned with the anatomy of the parts as well as the position of the bone with reference to the trunk. This bone is the earliest to ossify in the body. Its primary center appears in the sixth foetal week and at birth the entire bone is ossified except the two extremities. The true epiphysis appears at the sternal end at from fifteen to eighteen years of age and unites usually at nearly twenty-five years of age. Despite this late union epiphyseal separation is extremely rare, there being one case reported (Heath). The early ossification of the bone plus the unusually thick periosteum (J. Wm. White)[2] at a time when all other bones are flexible, makes this fracture occur most often in youth. Authors variously state that from 30 to 50 per cent. of the fractures of the clavicle occur under ten years of age. In a series of 500 cases at the University of Pennsylvania Hospital, the incidence was 41 per cent. Slesinger[46] found that of 458 consecutive fractures of the upper extremity in the out-patient department of Guy's Hospital, 77 cases or 16.8 per cent. were of the clavicle and that displacement was due to fracture violence and not muscle pull. The clavicle being the only bony connection (the key) between the trunk and the upper extremity, renders it particularly subject to trauma as all falls upon the upper extremity are of necessity transmitted to this bone. And yet nature has done much to strengthen this weakness in every part of the bone with one exception, namely, the exposed outer part of the middle third, and it is in this portion that fracture most frequently occurs, because it is the junction of two curves; it is the thin portion of the bone and it is not reënforced here by ligaments or muscles. Bennett[1] states that the position of the ligaments no doubt localizes the fracture here rather than any bone weakness, since experimentally the clavicle does not break at this point from longitudinal compression.

The function of the clavicle is essentially that of a " strut " (Cotton)[108] which holds the arm and scapula away from the body. In this function it is unsupported and must bear the force of any blow that tends to drive the shoulder inward or forward and must to some extent withstand the strain of any blow from above, or of any strain tending to pull the arm downward. For this reason and because of its exposed position it is frequently damaged, usually in the form of a fracture. It owes its existence to the function of abduction (G. G. Davis)[109]. Without a clavicle, abduction is practically wanting and when, in man, the clavicle is broken, he is temporarily reduced to the condition of those animals which have no clavicle, i. e., the horse and cow, and like them is able to move the arm backward and forward but not to abduct it properly; this is an important diagnostic symptom of injury.

In order to properly treat this fracture, the deformity and what factors cause it must be well understood. They fall into two groups, muscle pull and gravity (Figure I). What happens when the bone breaks? The inner fragment remains practically unchanged in its position, possibly it is drawn up slightly by the sterno-cleido mastoid muscle. This is but slight as the costo-clavicular ligament is never broken and so acts to combat the muscle action. The displacement occurs by virtue of the freedom of motion in the joint, resulting from the costo-clavicular ligament acting as a fulcrum. The outer fragment is the real offender in the deformity. The shoulder drops downward, forward and inward. The outer fragment goes with it and at the same time the inner end of this fragment is directed backward. The downward displacement is due to the latissimus dorsi, the pectoralis major and minor muscles and gravity; the levator scapulae, the pectorals and the latissimus dorsi draw it inward and cause the overlap; the forward deformity is due to the serratus magnus and the pec-

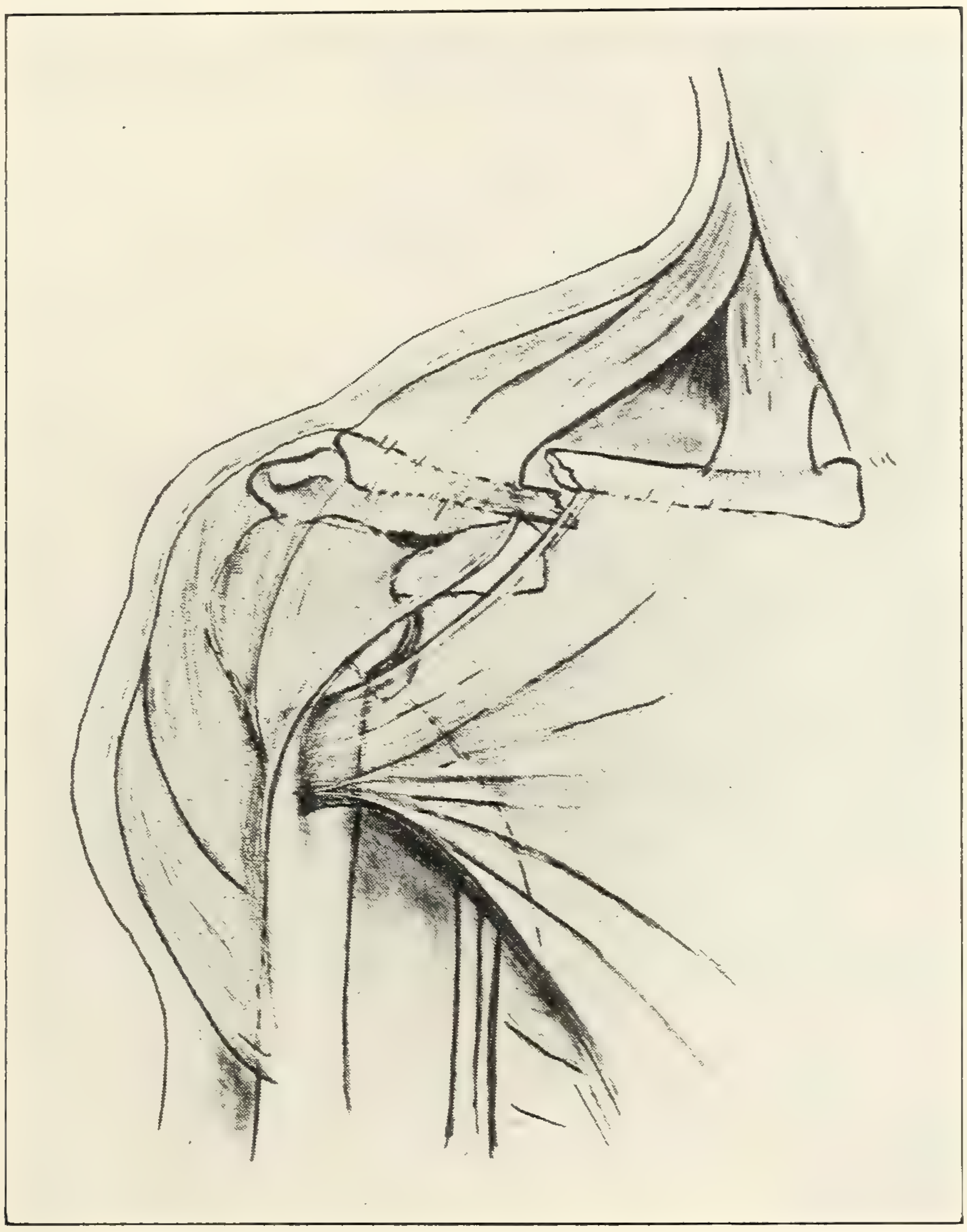

FIGURE I. Effect on fractured clavicle of muscle pull and gravity.

torals. The compound slope, due to the conical shape of the bony framework of the chest, accentuates the downward and forward slumps of the shoulder (Figure 2).

This position of the shoulder occurs in any fracture of the shaft of the clavicle in which there is separation of the fragments whether at the extremities or in the shaft itself. At the outer extremity the resultant deformity is almost nil, because of the coraco-clavicular, acromio-clavicular and the coraco-acromial ligaments. Should the fracture, however, be proximal to the conoid ligament the shoulder will show the characteristic deformity. Fractures near the sternal end give but little change in shoulder position in the average case, provided the costo-clavicular ligament remains intact.

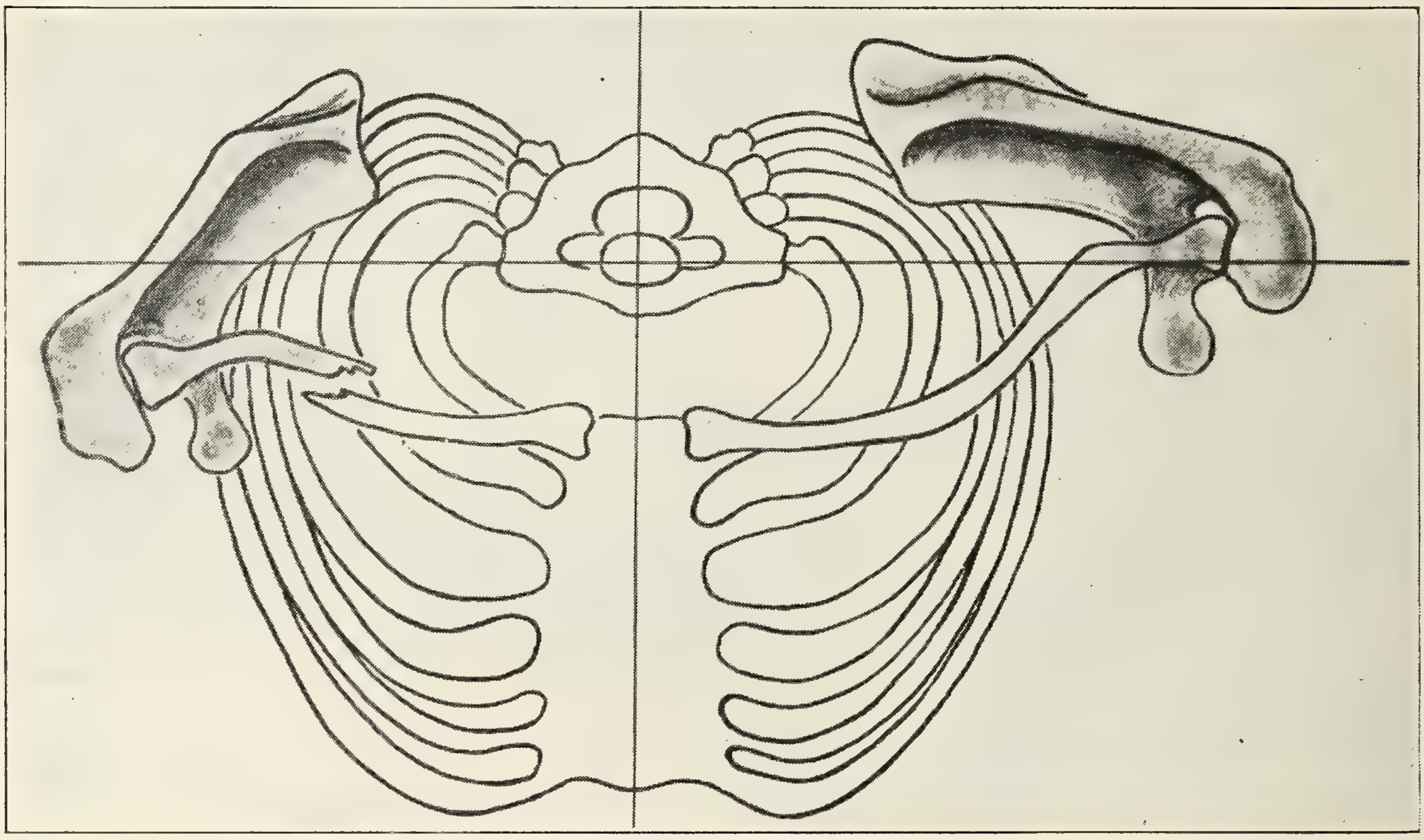

FIGURE 2. The conical shape of chest accentuates the downward and forward slope of shoulder (see also figure 5).

Etiology. In the new born the fracture is due to the compression incident to the passage thru the birth canal with the associated force applied by the hand of the obstetrician. This is usually of the incomplete type and occurs at the common site. Amreich[42] (1923) has written an article on the prevention of fracture of the clavicle in Veit-Smellie's maneuver. In our series there were 10 cases of birth fractures. After birth 94 per cent. of the injuries were due to indirect violence, described as a fall from a height in 175 cases, fall on the shoulder in 93, automobile accidents in 55, athletics in 24, etc. Fractures due to direct violence were usually transverse and in the outer third of the bone, while the rare fracture due to muscular action occurred in the inner third of the bone. Polaillon[3] quoted by Treves from a careful analysis of reported cases concludes that " the muscles that break the bone are the deltoid and the clavicular portion of the great pectoral. In no case does the fracture appear to have been produced by the sterno-mastoid muscle. The commonest movements producing fracture appear to be violent movements of the limb forward and inward or upward. The resultant deformity is an anterior bowing." A fracture has been described as due to a simultaneous depression and backward thrust of the shoulder, angling the bone over the first rib. In this series of 500 there was only one such case. Some of the rarer fractures are fractures of the middle third, secondary, bilateral, syphillitic and pathologic fracture. Stoccada[67] has reported the first, Lefevre and Gaignerot[61] claim that secondary fracture is very rare but in America it is not uncommonly met with in football accidents, especially in previous fractures that have overlapped in uniting. Dubs[79] has reported a case of bilateral fracture of the clavicles, and, strangely enough, in the middle thirds. He treated the case by securing the elbows together posteriorly, while in a case of bilateral sternal (end) dislocation he tied both elbows anteriorly across the chest. Tritto[55] likewise reports a fracture of both clavicles and Guinard collected 40 cases. Some occur simultaneously and some consecutively; they are due to direct violence and results are good as far as union and function is concerned.

Pathologic fractures are less common than of the humerus. Achard and Welter[36] describe their occurrence in syphillitics. Lussana[103] presents two due to sarcoma and cites others in the literature. They may occur with carcinoma and trivial traumata. Glover[110], Hunter[111] and Gotz[112] reports cases due to osteogenesis imperfecta.

In adults the fracture is usually a simple complete one of the oblique type, although occasionally there is comminution even in the absence of direct violence. In children the fracture is usually incomplete. After puberty, however, the complete fractures are more common and the line is usually transverse. Football is responsible for many of these.

Fracture of this bone is rarely compound and when so, the trauma is of the direct type, in the nature of gunshot or war wound, or associated with severe crushes or lacerations that greatly outweigh the fracture in the importance of treatment.

Diagnosis. The typical adult fracture offers no problem in diagnosis. There is usually the history of trauma, local pain and tenderness and the typical angular deformity, usually with overlapping, the shoulder being downward, forward and inward. The patient assumes a characteristic attitude, with the head inclined toward the injured side, the chin being directed toward the opposite shoulder. This is not so often noted in children. The forearm, flexed to a right angle at the elbow is supported and pushed upward by the other hand. Crepitus and abnormal mobility are readily demonstrated by direct palpation or by raising or lowering the arm. In the absence of deformity local tenderness and pain referred to the site of injury on voluntary raising of the arm, usually are sufficient, to make a diagnosis. Fracture near the extremities may give considerable deformity confusing the picture with dislocation possibilities. This is especially true at the outer end where an acromio-clavicular dislocation with or without a fracture of the tip of the clavicle occurs very frequently. A roentgenogram should clear the picture.

In children, pain on being lifted by the arm or only slight disinclination to use the part, may be the only signs of possible fracture. Careful examination will reveal tenderness or a tumefaction at the suspected site. In examining these little patients one should first gain their confidence, then manipulate the uninjured member for a while, before directing attention to the injured limb, which should be examined gently beginning with the hand, then the wrist, elbow and shoulder. Failure to carry out these procedures has more than once resulted in an erroneous diagnosis of a forearm or elbow injury because of the cries of the little patient, not from pain, but from fright. In such a situation a splint has often been worn on the forearm or humerus for a week until the mother, by calling attention to an increasing lump on the clavicle, corrects the diagnosis.

Roentgen-ray examination. Except in dislocation of the inner end of the clavicle the antero-posterior or postero-anterior view is the only one that can be made, and dependence upon stereoscopic films as a routine measure is a safe practice for both diagnosis and treatment. In the very young the greatest care must be observed in making the exposure while the clavicle is as nearly parallel as possible with the film, as otherwise the shadow will appear almost end on especially if there is a Velpeau or Sayre dressing applied. Greenstick fractures in the young with little deformity require the very best detail possible. Fractures close to the inner end of the body present the greatest difficulty and the exposure should be made postero-anterior so as to have the vertebral shadow clear those of the inner ends of the clavicles. A well directed lateral view (sitting posture) will serve to distinguish a fracture of the inner end from a dislocation. Quesada[28] advocates taking two views at right angles to each other with the patient face down on the films. He has found this the most satisfactory means of obtaining the most information with regards to position and comminution. Keith and Hall[83] have contributed an article on gunshot injuries of long bones including the clavicle. This type of injury is most seen in war.

Complications. Injuries, the result of the fragments, are very infrequent. Cases are reported of nerve, vessel and lung injury but these are extremely rare due to the bone fragments. Lotsch[31] of Leipzig (1920) and Mutel[32] (1920) both describe plexus injuries. This is probably due to the fact that the periosteum is extremely tough and thick, being further

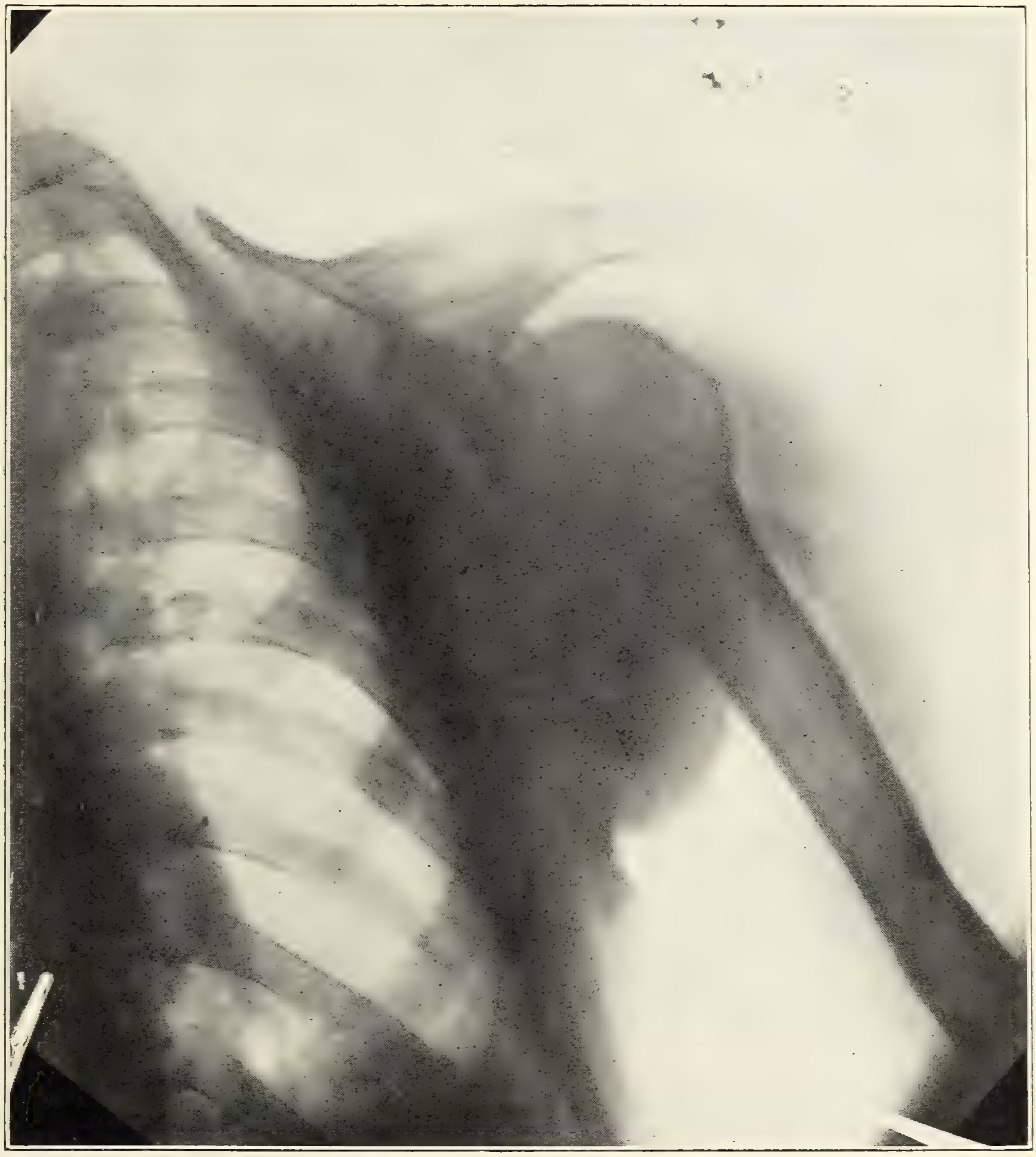

FIGURE 3. Unusual treatment of a compound comminuted fracture of the clavicle by excision resulting in excellent function.

strengthened on the inferior aspect by the subclavius muscle. These all, however, have occurred as a result of the same trauma. Associated bony injuries, however, are not unusual. In this series associated fracture of the scapula occurred in thirteen cases, dislocation of outer end of the clavicle in six cases, fracture of the humerus in six cases, fracture of one or more ribs in nine cases, dislocation at the shoulder in three cases, fracture of olecranon in three cases.

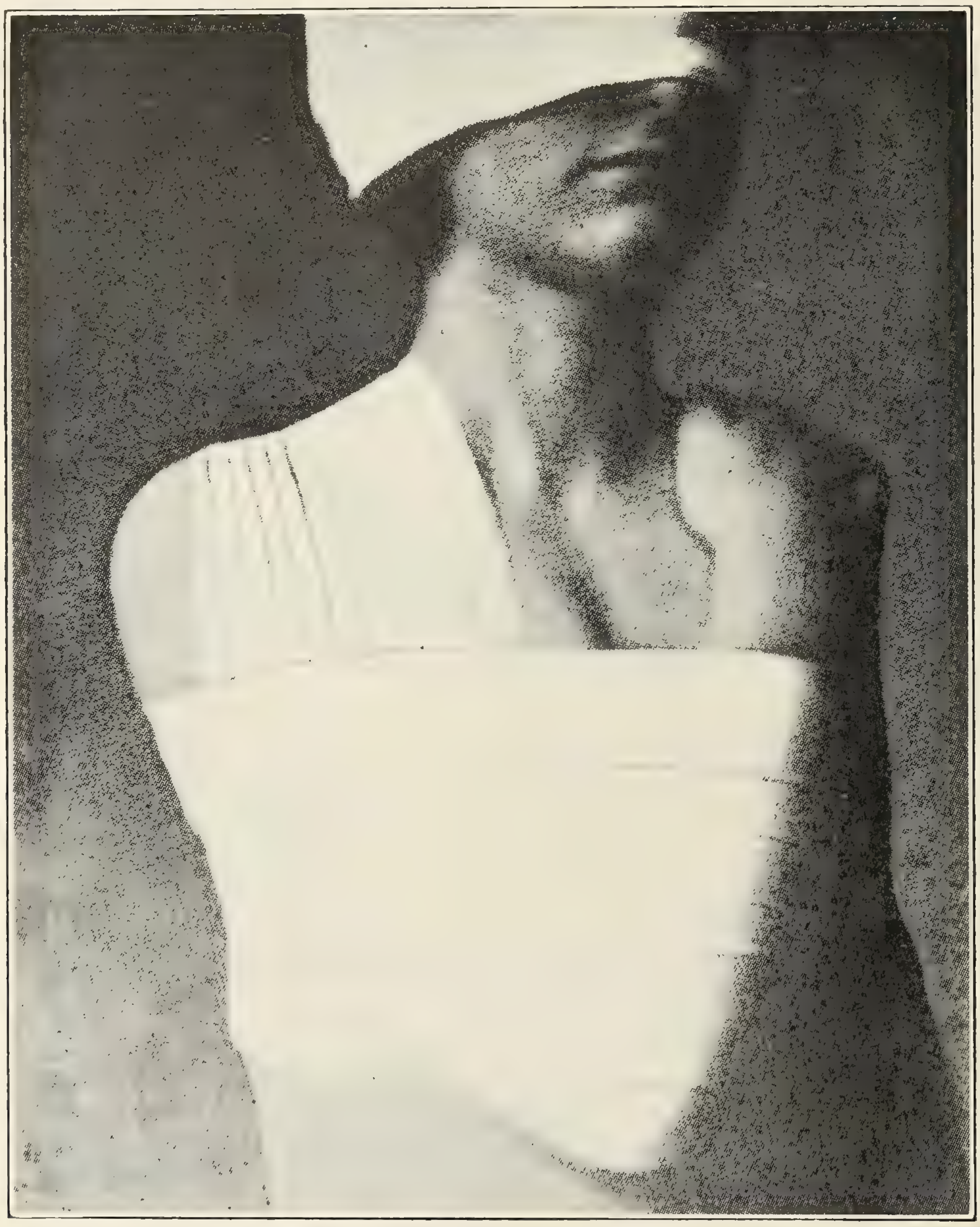

FIGURE 4. Velpeau dressing.

Treatment. During the last ten years there have been somewhat more than 100 articles published on fractures of the clavicle, many of which were descriptive of a new type of fixation dressing. Bela V. Mezö[4], in 1921, collected 85 published methods of fixation for this fracture. This multiplicity can mean but one thing, namely that we as yet do not have a satisfactory method of handling all our fractured clavicles. Since 1921 several more new methods have been described showing that the surgeon is still on the hunt for a satisfactory ambulatory treatment that will be comfortable, restore function and minimize deformity. Hippocrates over 2000 years ago described fractures of the clavicle and advocated (Kahle)[47] placing the shoulder " out, up and back "! There need be no fear of incomplete union as this is so rare in closed cases as to be ignored. Union occurs despite the fact that fixation is not complete, as motion occurs 18 to 20 times a minute with respiration. Union will occur and despite deformity a good function will result. This is shown by the

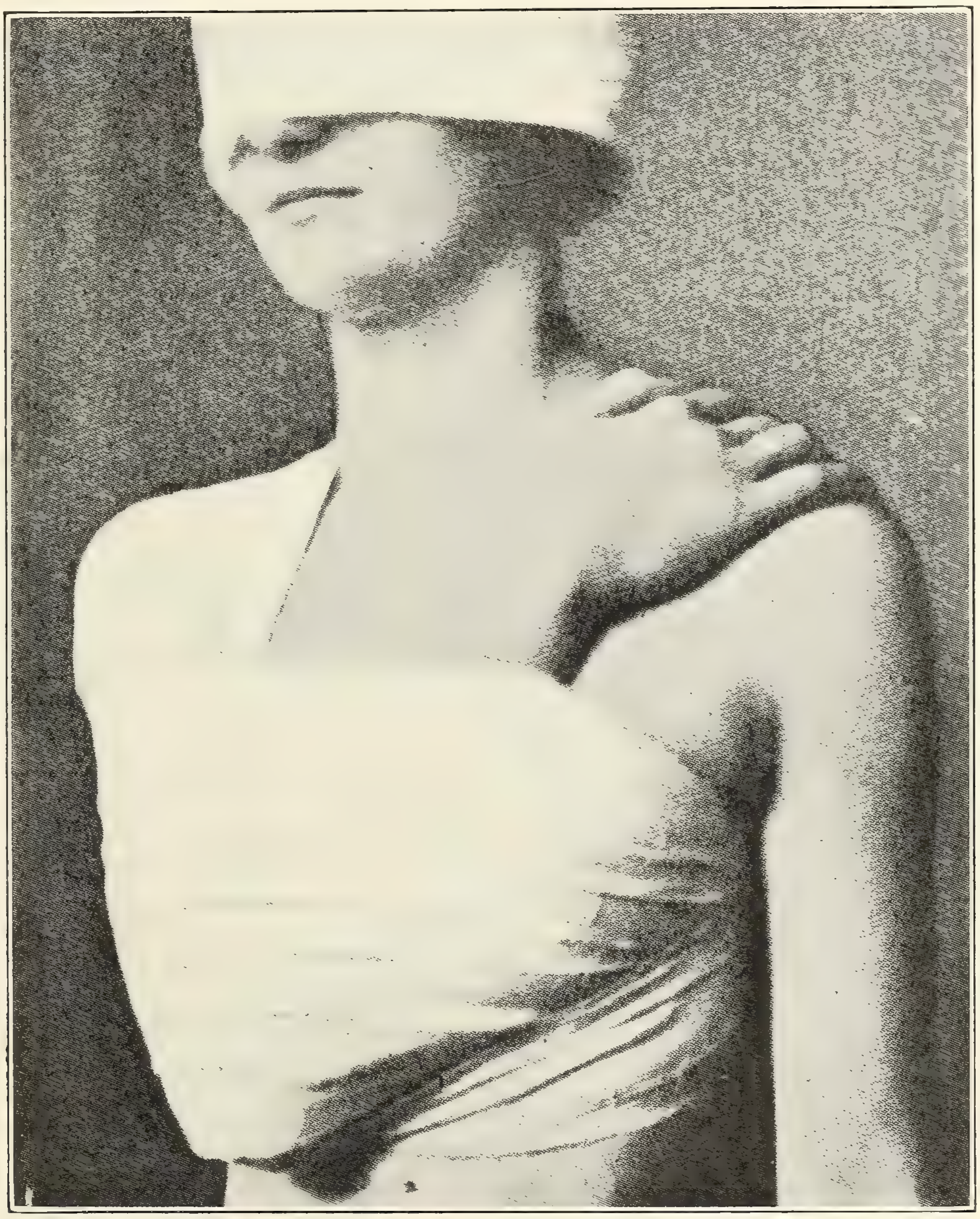

FIGURE 5. Velpeau dressing.

results in innumerable cases in which the fracture was never treated, due to oversight or the seriousness of the injuries. Henderson[107] of the Mayo clinic found one case of non-union of the clavicle in a review of 221 cases of non-union culled from approximately 1000 cases of old fractures consisting of malunions, delayed unions and so forth during a period of ten years. The case was treated successfully by plastic operation. Furthermore, cases with complete removal of the clavicle have excellent function (Figure 3).

Incomplete or greenstick fractures can well be handled with a Velpeau (Figures 4–5) or Sayre dressing (Figure 6), or any one of their modifications*. These cases require protection for two to three weeks, a sling only for another week and recovery is complete. In those cases of complete fracture, difficult to retain in position, the type of treatment will depend on the patient's desires. If they wish the least possible degree of de-

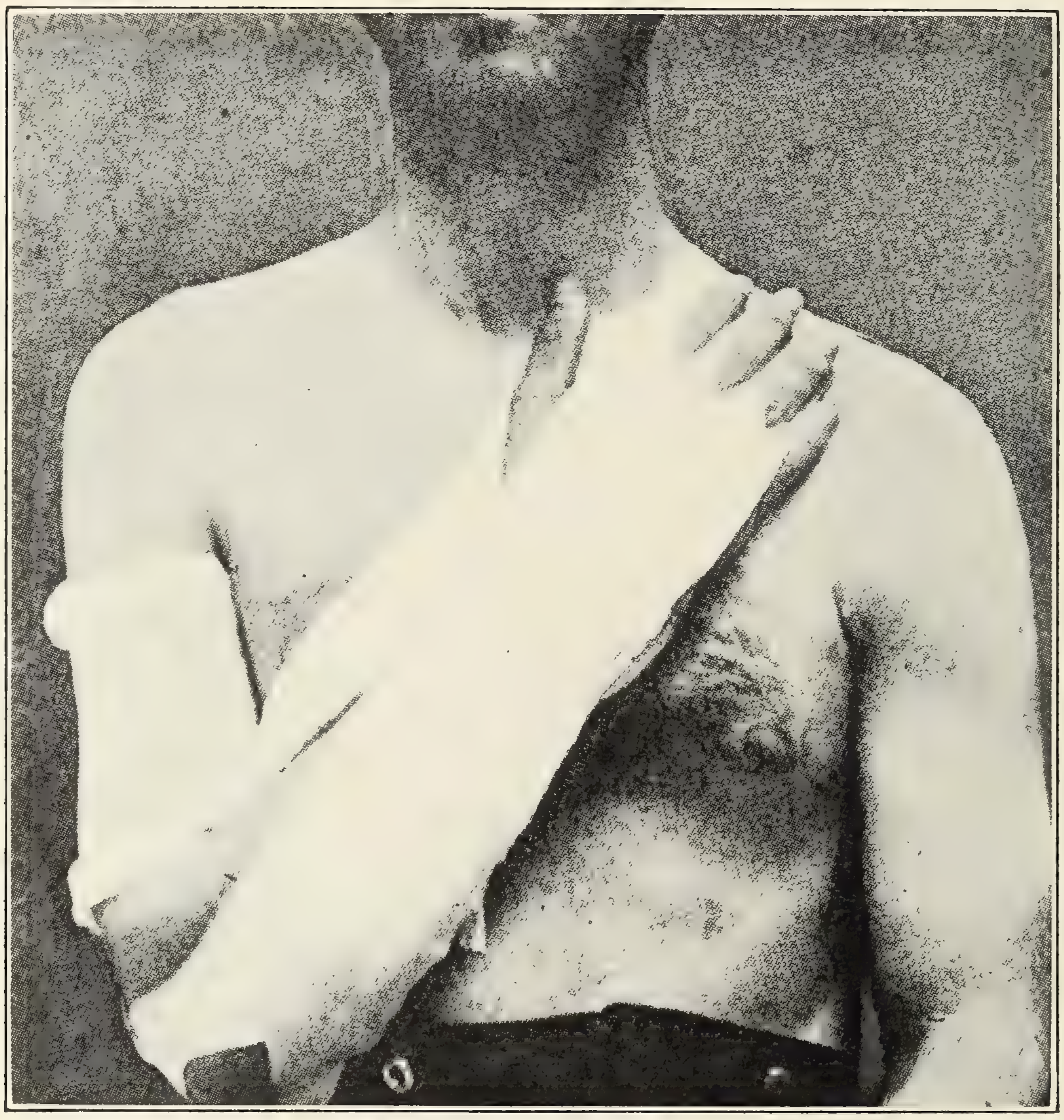

FIGURE 6. Sayre dressing.

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* Editorial foot note. Proper padding should be used to keep opposing skin set faces apart. It is omitted from the illustrations for sake of clarity.

formity and the ambulatory dressing does not maintain proper reduction, then they must submit to the bed or recumbent treatment. If they are willing to suffer some discomfort and will be satisfied with a deformity of a lump and a narrow shoulder, then a choice of one of the other 87 known dressings can be used.

These dressings will act to force the shoulder upward, outward and backward and to hold it there. The forces that must be combatted are muscle pull and gravity. The writer feels that muscle pull is negligible but that gravity is the important thing. The contour of the ribs is such that if the shoulder is pushed back, it will of necessity be pushed up (Figure 7). In other words if we can hold the shoulder back it will stay up and the outer fragment will fall into place. This backward position is poorly maintained by any and all of the dressings, bandages or adhesive plaster, which bind the arm to the trunk as the clavicle, acting as an outrigger to hold the shoulder away from the chest, is broken. The natural position of relaxation or slump is with the shoulder downward and forward (Figure 6). Hence muscle relaxation will not accomplish our backward position. If the shoulder is pushed back, the scapula will lie flat on the posterior aspect of the ribs and conversely if the scapula is flattened on the

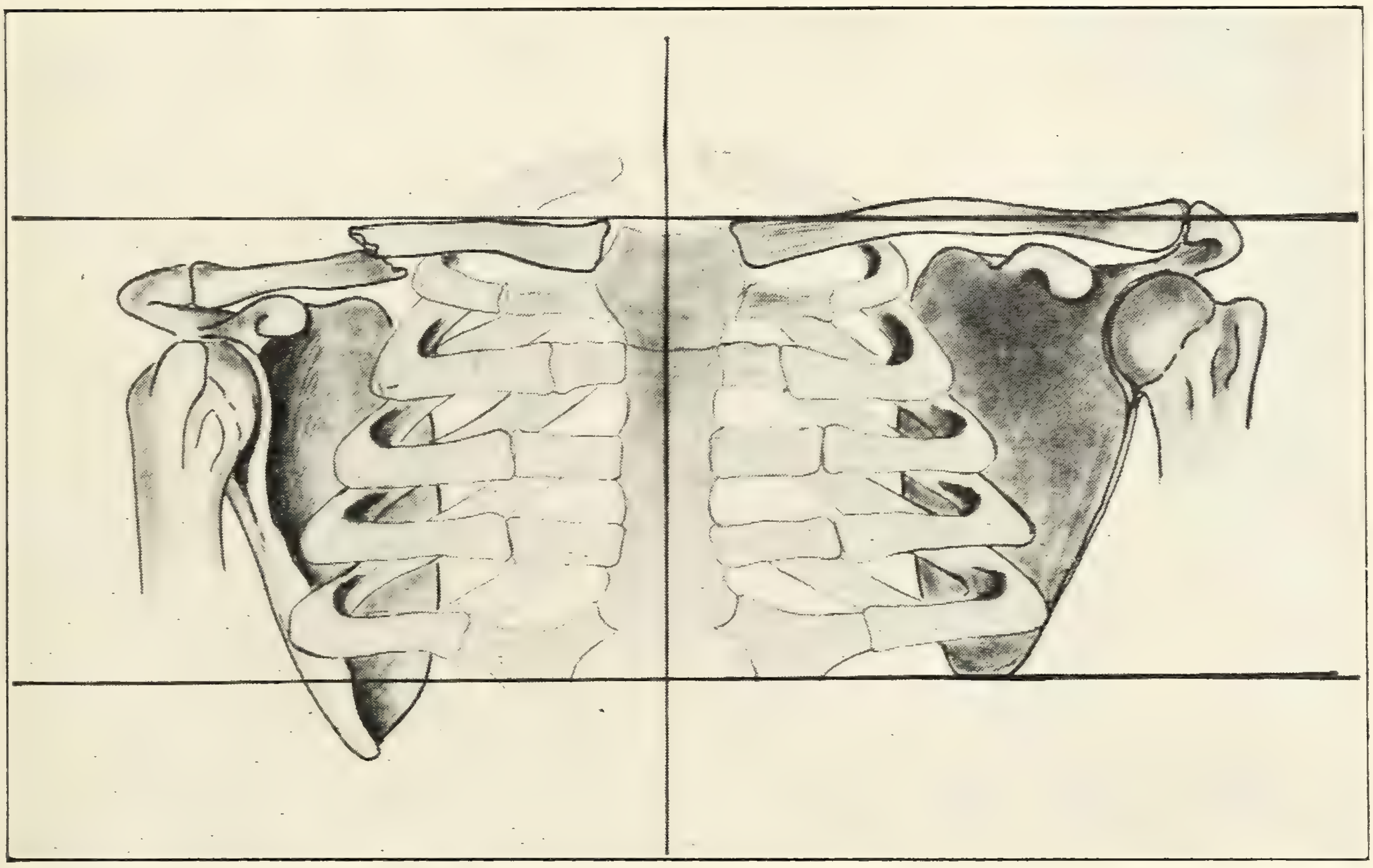


FIGURE 7. The slope of the injured shoulder is downward and forward: note the positions of the respective scapulae.

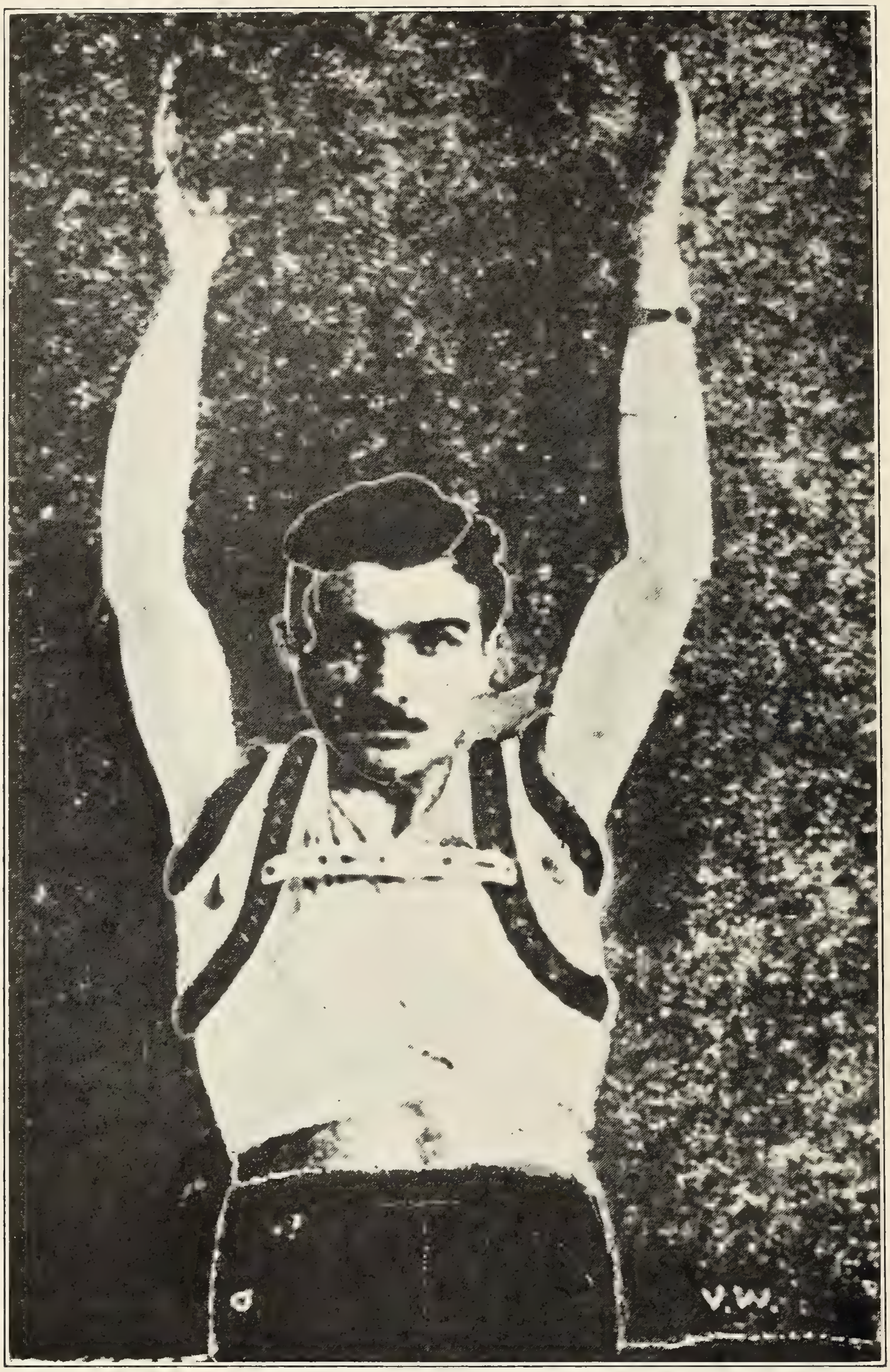


FIGURE 8. Masmonteils apparatus illustrating the mobility permissable with this form of treatment.

VOL. I. 729.

ribs the shoulder will be carried up and back. Two types of treatment will accomplish this, the posterior splints and the recumbent treatment. The posterior splints such as those of Landry[78] and Hawley[84] permit the patient to be ambulatory and to use the limb, but it is exceedingly difficult to make them comfortable. Furthermore, although they may be applied with the fracture reduced, the bandages, straps, etc. soon become loosened and the slump in the shoulder occurs, and pressure against the axillary folds cause irritation and even pressure ulceration. Richards[92] used the Landry splint in 50 cases and only one complained.

On the continent various braces which are principally a posterior figure of eight are applied and the patient often permitted immediate or early use of the upper extremities. Masmonteils apparatus[53] is shown in Figure 8. The immobilization advised by Lüthi[13] and by Konosevich[12] while holding the fragments in place is, practically speaking, more annoying and uncomfortable to patients than other methods. It consists of carrying both elbows behind the posterior plane of the body and maintaining them there by passing a broomstick or similar object posterior to the body or anterior to both flexed elbows (Figure 9).

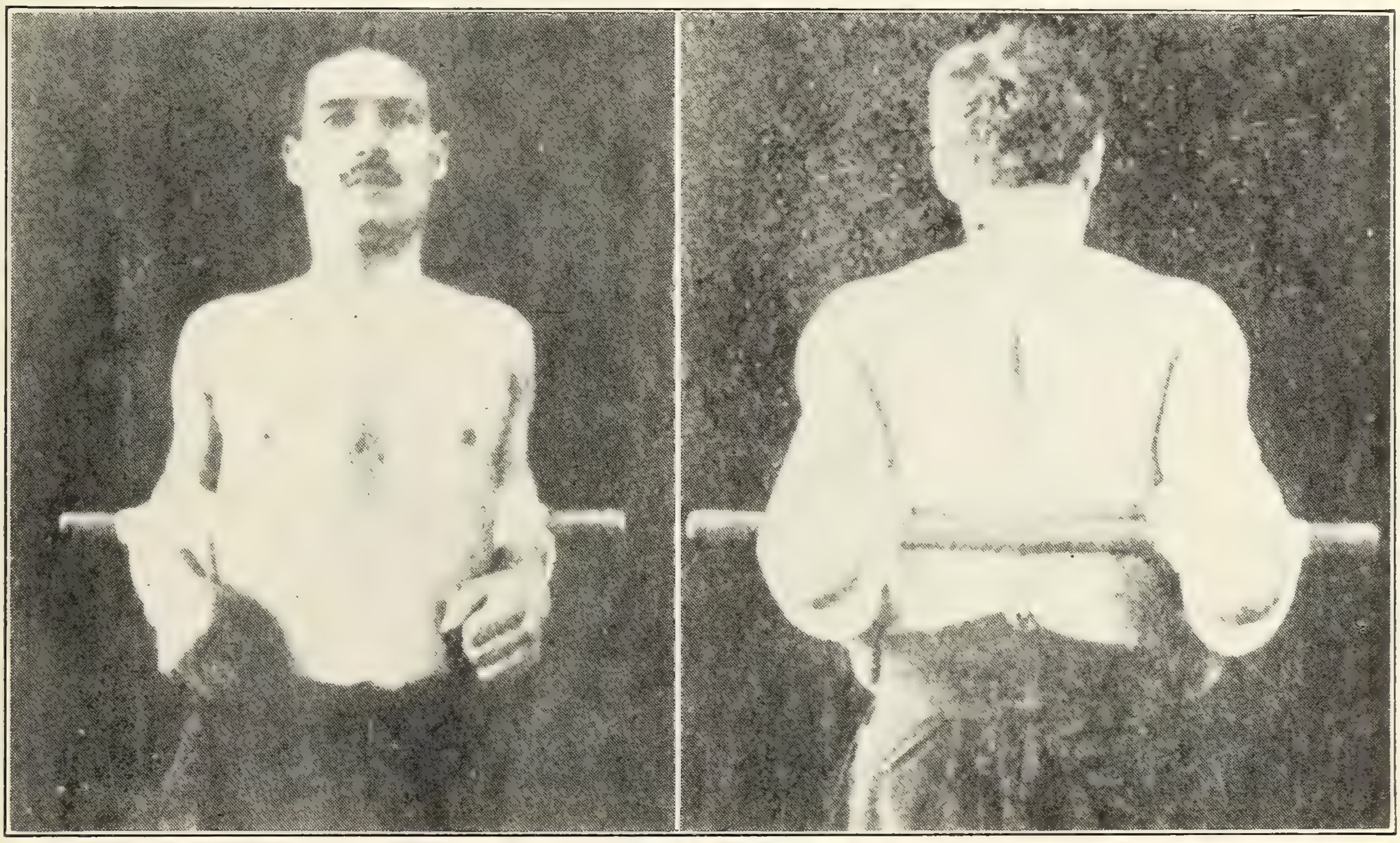


FIGURE 9. Immobilization of Luthi or the "elbows back position".

Most of the numerous dressings reported have been devised with the hope of getting comfort and but few, if any, have succeeded, and those only that tend to hold the scapula back rather than up by support under the elbow, axilla or forearm. It seems to the writer that as *deformity cannot generally be prevented by ambulatory methods and that good union and function are practically universal, comfort is the keynote.* The writer has used with success an adhesive dressing laced with elastic bands, augmented by a forearm sling (Figures 10–11 authors dressing). This is especially useful if the fracture is complicated by a subluxation at the acromioclavicular joint.

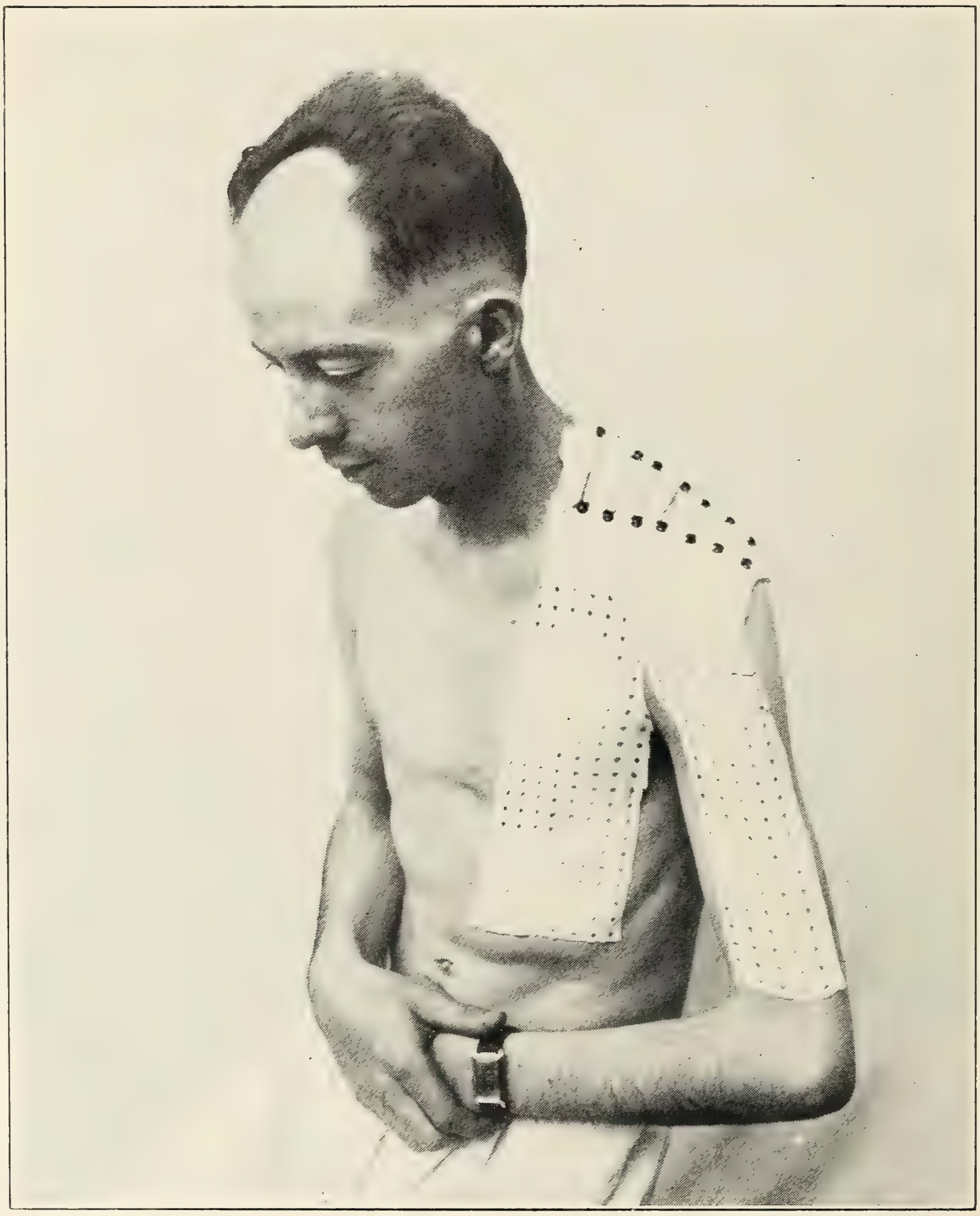


FIGURE 10. The Author's adhesive dressing. Antero-lateral view.

VOL. I. 729.

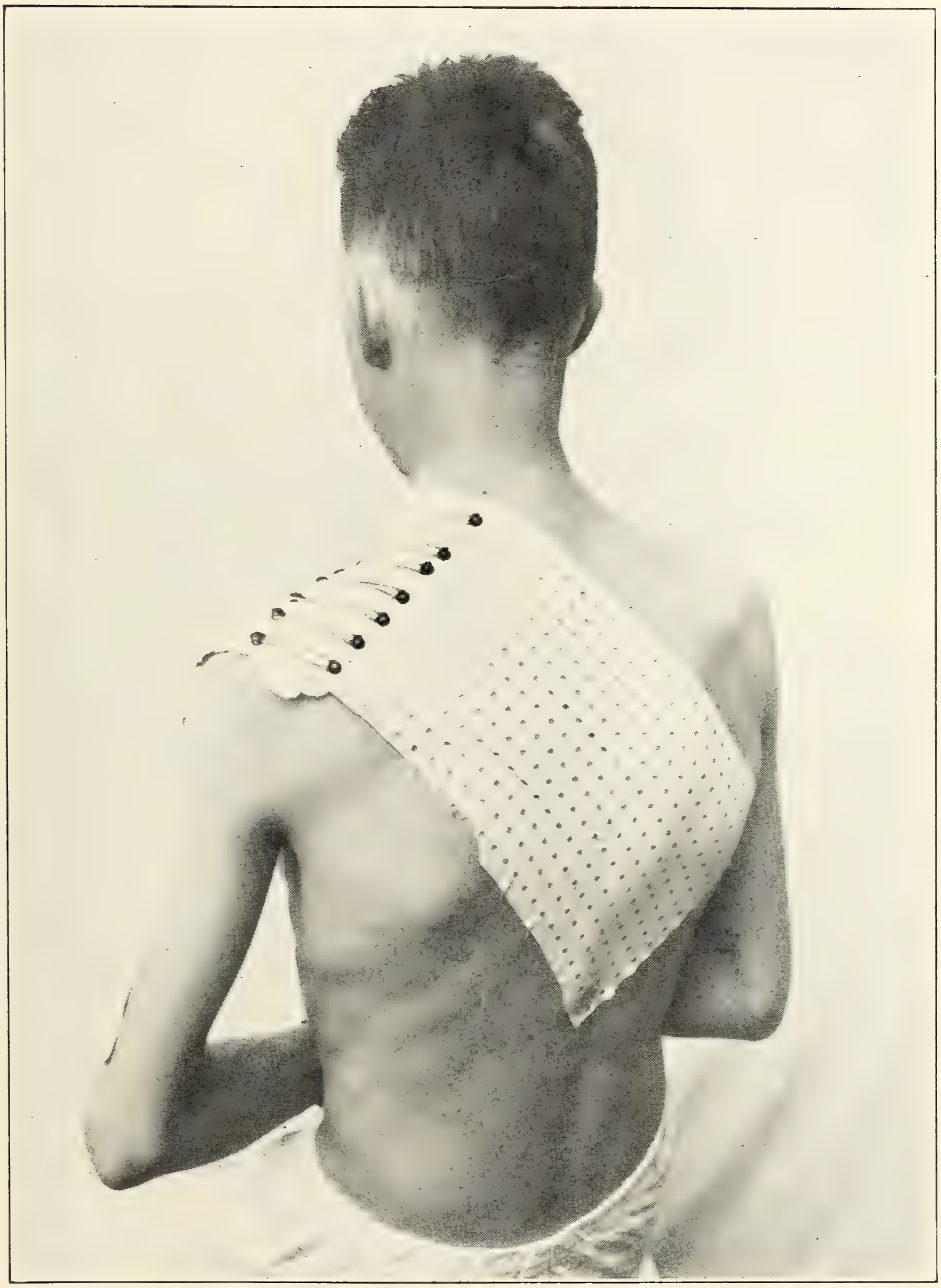


FIGURE 11. The Author's adhesive dressing. Posterior view.

Some writers advocate plaster of paris casts or moulds, with traction efforts exerted upon the shoulder. This seems unusually cumbersome and burdensome and uncomfortable except for possibly selected cases.

The recumbent treatment although somewhat tiresome gives the best anatomical results. It is applicable for birth fractures as well as for all other ages. It is virtually compulsory in bilateral fractures, badly comminuted fractures, many fractures complicated by wounds, multiple fractures and in those patients demanding a minimum deformity. Figure 12 illustrates a case of the latter where other methods would have been contra-indicated.

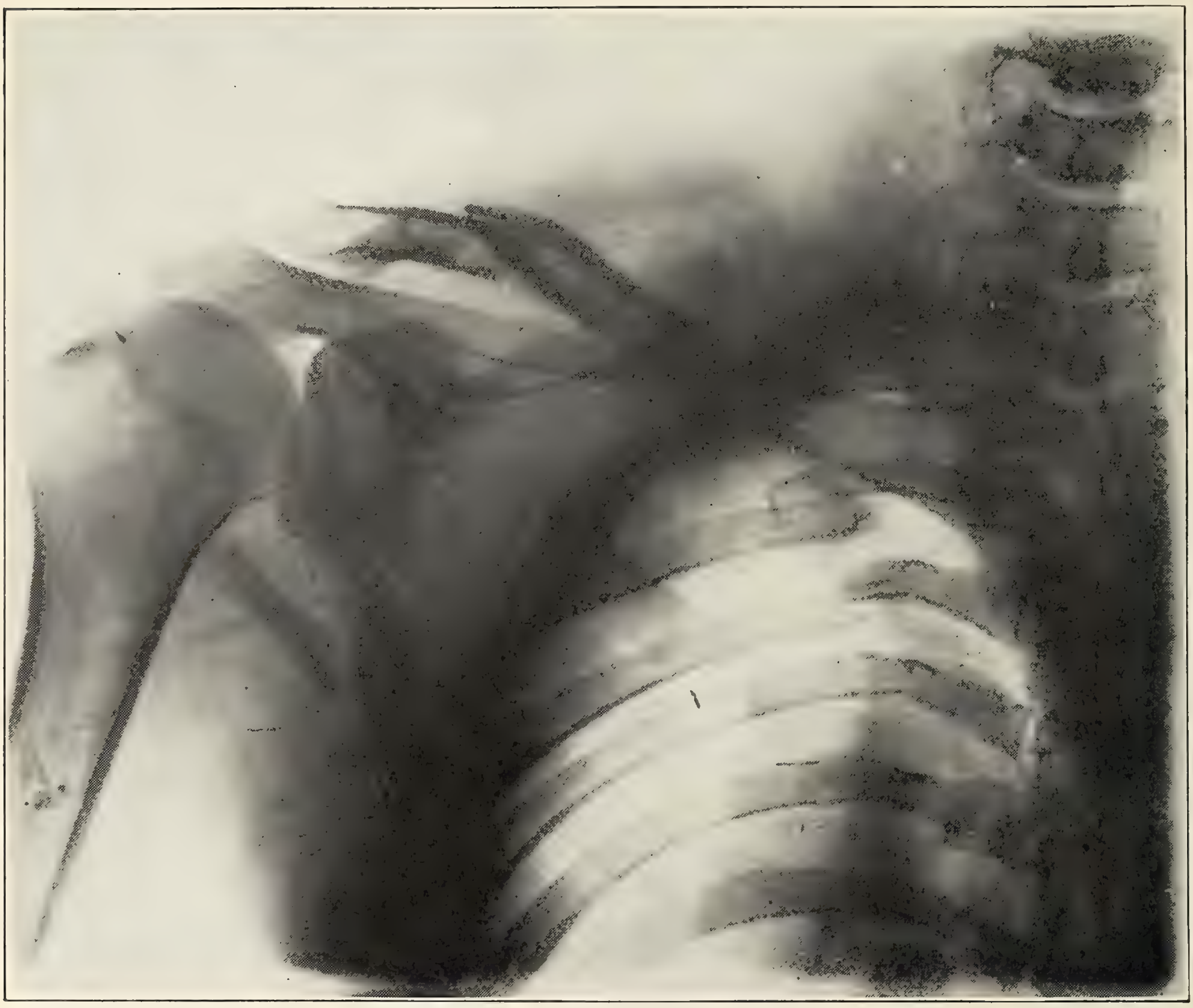


FIGURE 12. Fracture of the clavicle, scapula and upper ribs with partial collapse of lung. Recumbent method of treatment obligatory.

Furthermore, in young athletes with a transverse fracture impossible of being reduced or maintained in reduction by ambulatory methods, the recumbent method is preferred, because several cases with overlap-union have again fractured through the same site, the next year when strenuous sport has caused a similar trauma.

The recumbent treatment was popularized by Couteaud (Figures 12, 13, 14). He places the patient in his first position which is lying on his back on a firm flat mattress with the arm hanging over the side of the bed, a pillow is placed under the head but not under the injured shoulder. This position is held for an hour to an hour and a half, when the fracture will have become reduced. Then the second position is assumed, by

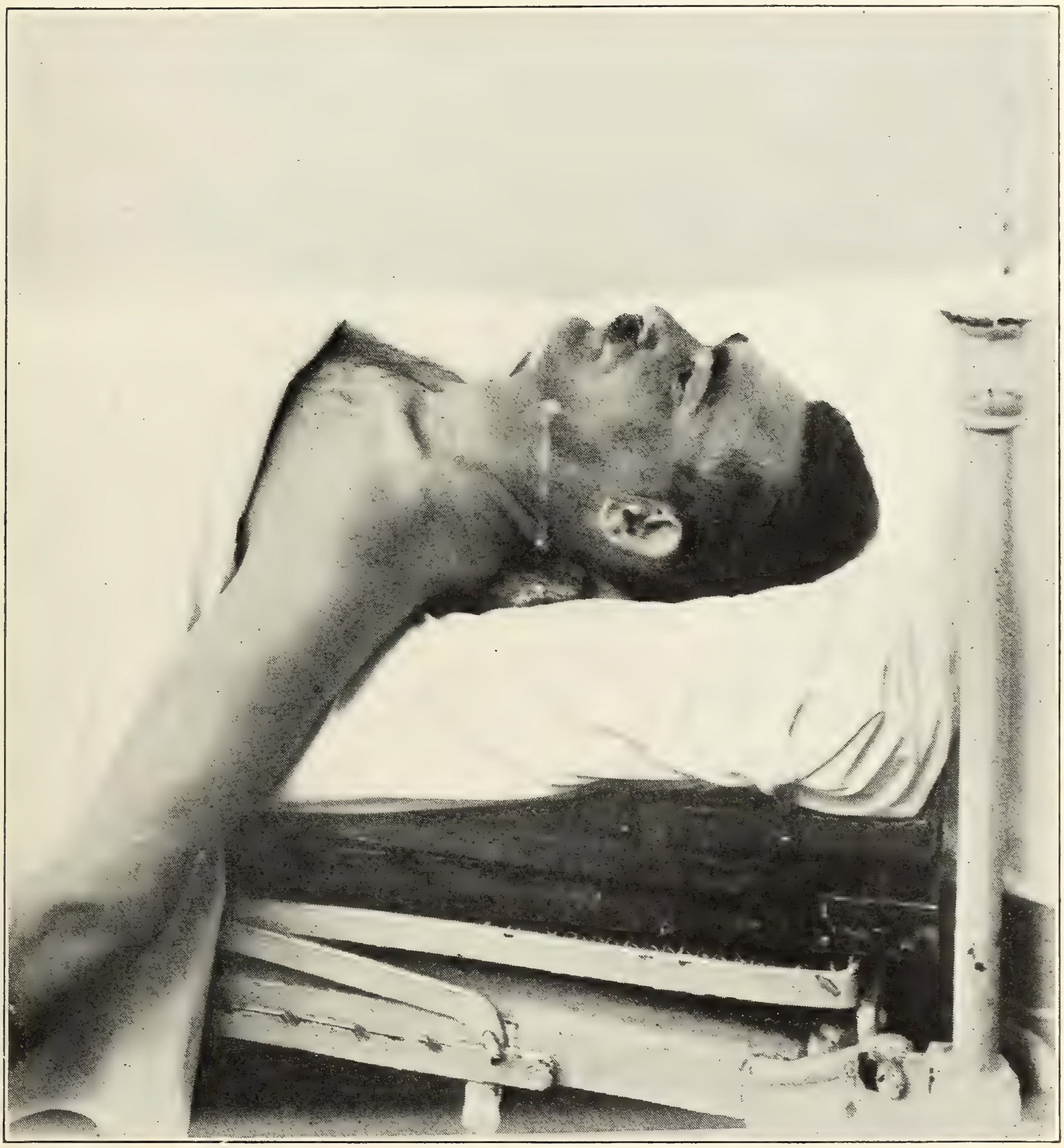


Figure 13. Couteaud's method of treating fracture of clavicle. First position or position of reduction.

simply placing the forearm on a pillow on a bedside support, slightly lower than the elbow, but should not support the elbow itself, rather leaving it so that gravity still acts. A sling for the wrist to the side of the bed may be used. This is maintained for seven days.

Practical experimentation by an assistant with the " first position " found it unbearable after the first 45 minutes. The second position was comfortable.

Milliken[6] uses his own modification of the supine position in that he raises the head of the bed and fastens the upper limb of the affected side to the head of the bed, thus causing abduction and external rotation of the humerus. Weight traction is added (Figure 15). Conwell[7] also uses traction and recumbent treatment.

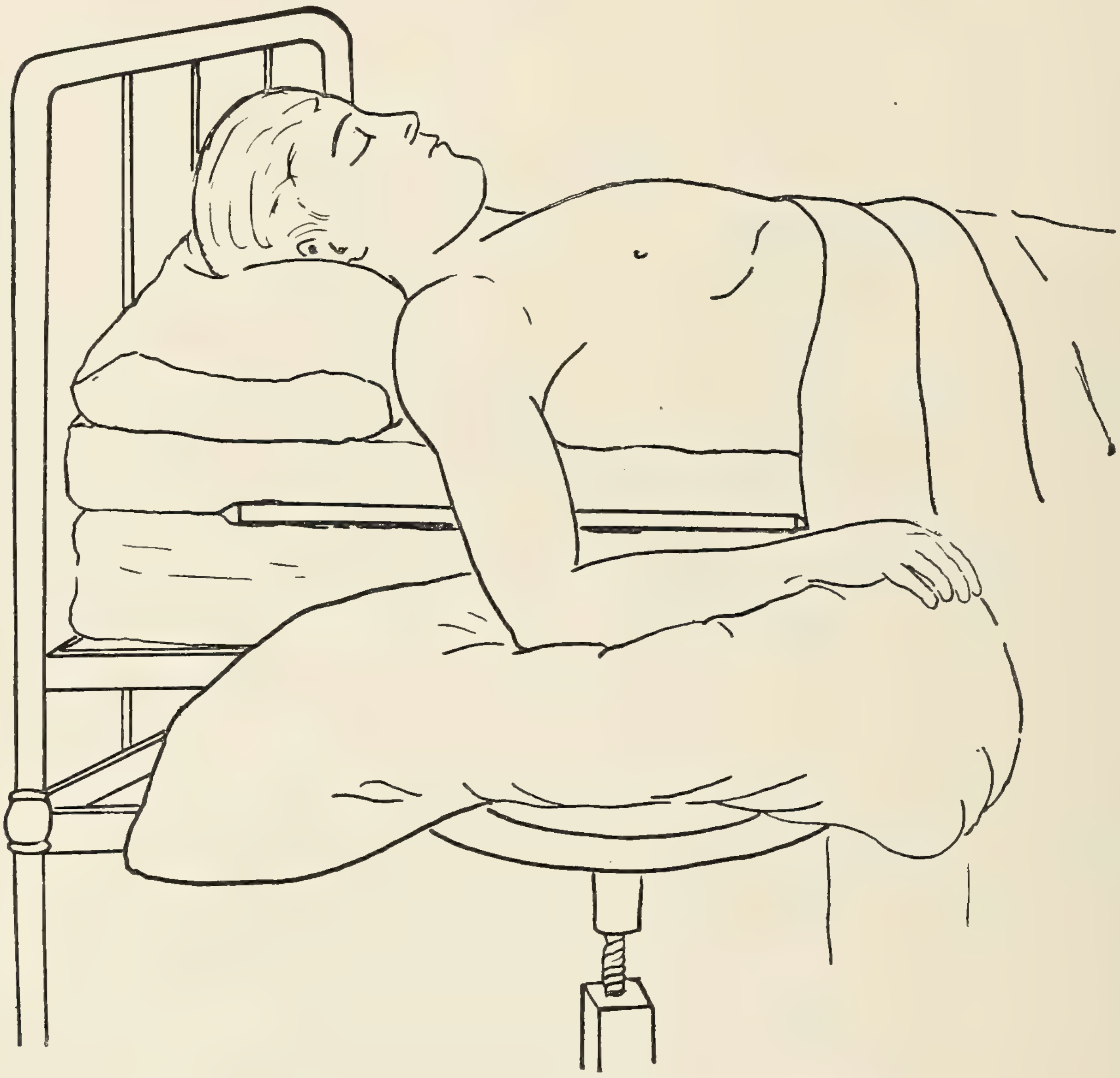


FIGURE 14. Couteaud's method of treating fracture of clavicle. Second position or position of immobilization.

Note: The weight of the upper extremity is not absorbed by the pillow. Gravity keeps the shoulder "back" and the board beneath the mattress presses the scapula against the chest and "up".

The simple recumbent position with a sand bag on the shoulders for weight and restraint reminder has been entirely satisfactory in the writer's hands. A flat bed, made so by a board beneath the mattress if necessary, a small head pillow, a loose wrist sling possibly, and a warning against raising the head by its own efforts, turning on the side unaided, or other motion in the shoulder suffices for a favorable beginning (Figure 16).

After two, possibly three weeks, an ambulatory dressing of the laced type, or other supports as chosen will be sufficient support for another one to two weeks. It is not well to permit shoulder sag too soon as it will result in angulation, excessive callus and deformity. The length of time in bed is governed by the rapidity of callus formation. Ten days usually suffices. Open reduction with plating, silver wire and other internal fixation, except in exceptional aesthetic cases, is to be frowned upon as non-union practically never occurs.

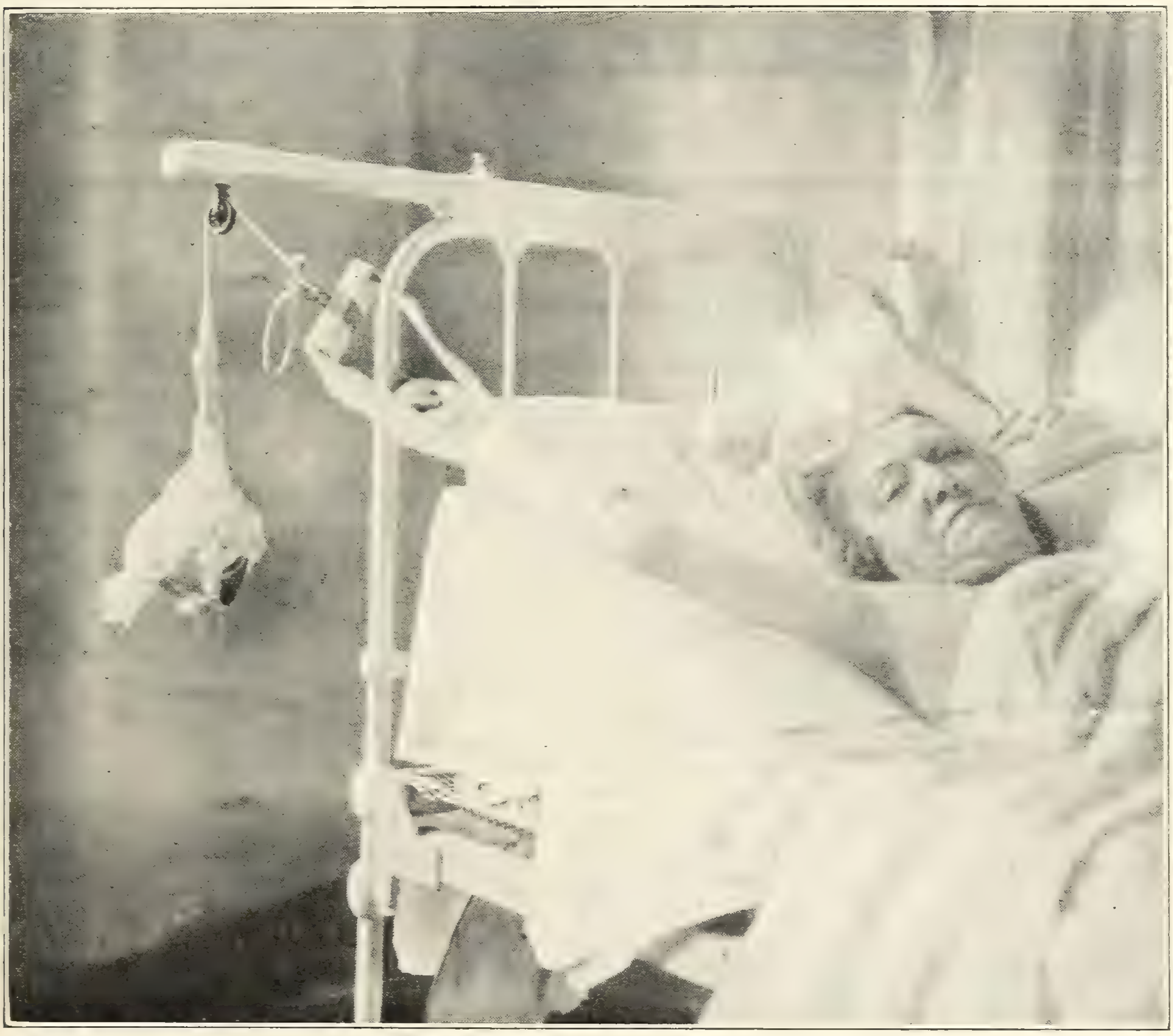


FIGURE 15. Milliken's method of treating fractured clavicles — recumbency, head of bed elevated by blocks and weight traction.

An unusual treatment for a badly shattered compound fracture, namely, surgical removal of the entire clavicle, was seen recently by the writer. This patient has excellent function (see Figure 3).

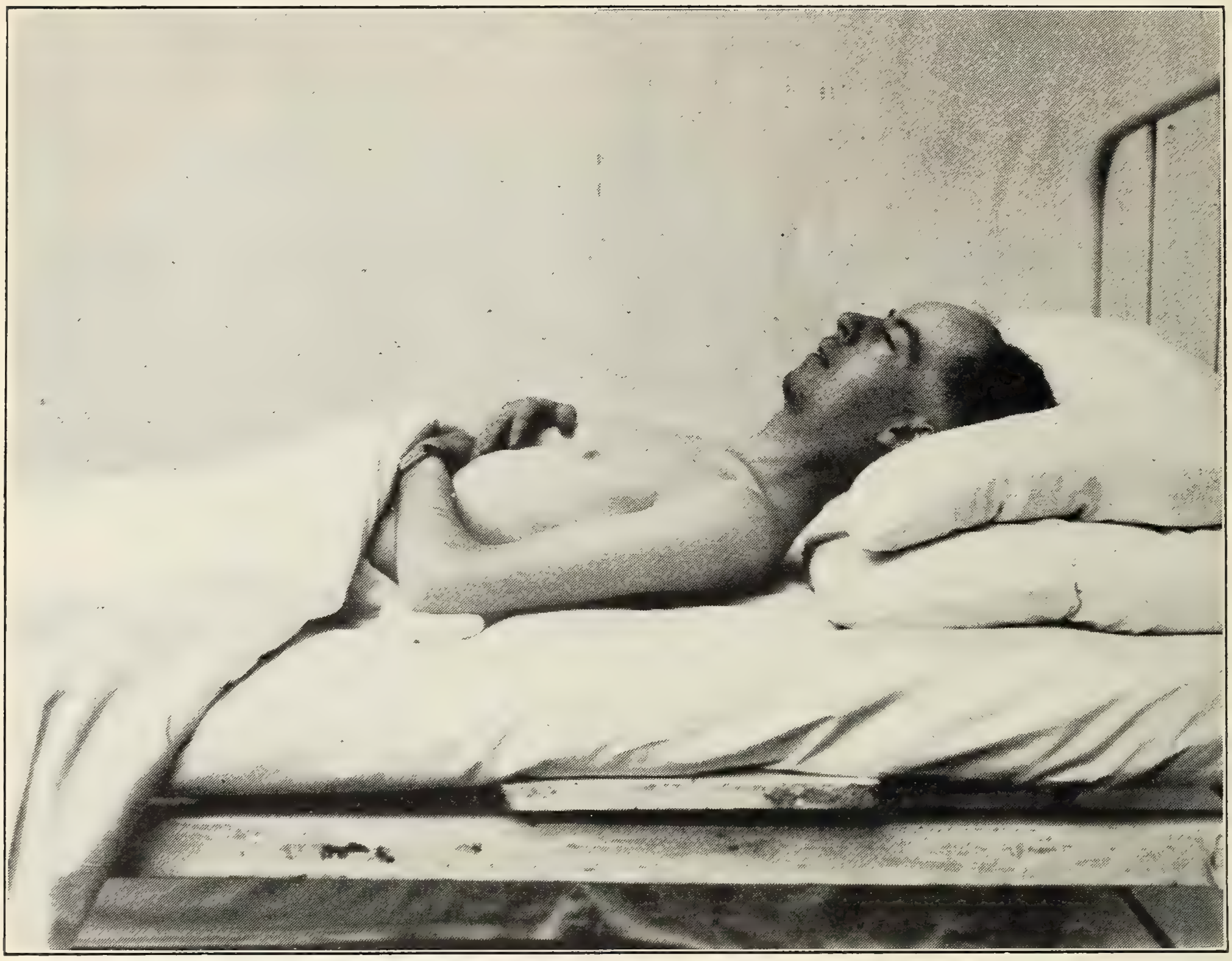


FIGURE 16. Simple recumbent position for fractured clavicle (sand-bag and sling removed for photographing).

SUMMARY

Ambulatory dressings for the fracture are generally unsatisfactory as regards comfort and anatomical perfection although function is almost universally all that could be desired. The multiplicity of methods points to the unsatisfactory state of such fixation. The recumbent methods which take cognizance of the necessity of a scapula flat on the chest will give the best results anatomically, as well as functionally. Complications other than associated bony lesions are very rarely due to the fractured bone itself. Open reduction is seldom necessary.

Epiphyseal injuries no doubt occur but can only be diagnosed clinically as due to the sternal location the X-ray is of little value. The authors, however, have observed cases in which after a fall on the shoulder, during the epiphyseal age, slight swelling, tenderness and pain over the sternal epiphysis have been complained of on pressure over the sternal end of the clavicle or on rotation and manipulation of the shoulder. Rest by use of a triangular sling or Velpeau dressing and the application of dry heat relieved the symptoms.

Epiphysitis of the sternal end of the clavicle has not been reported to the writers' knowledge. Heath reports a case of epiphyseal injury.

DISLOCATIONS OF THE CLAVICLE

A dislocation of either the acromial or sternal end of the clavicle or of both ends, may take place. Dislocation of the outer end of the clavicle is by far the most common. Of 528 dislocations at the University of Pennsylvania Hospital, 70, or 13.2 per cent., were of the clavicle. These were of the outer or acromial end. Eight, or 11.4 per cent., of these were complicated, mostly by fracture of the outer end. Diagnosis can always be made clinically of a dislocation of either end. X-ray examination is of little value for luxation of the sternal end but is helpful in revealing any attending fracture or epiphyseal injury to the outer end.

Dislocation of the acromio-clavicular joint usually results from falls or blows on the point of the shoulder and is aided by depression and inward rotation of the scapula. This carries the base of the coracoid upward against the clavicle, and as the clavicle is fastened to this by the coraco-clavicular ligament the only motion possible is an upward displacement of the acromial end of the clavicle, the coracoid acting as a fulcrum. Experimentally (Cadenat)[69] on the cadaver it has been shown that the conoid and trapezoid ligaments were so strong that the clavicle was broken when prying with a bar before the ligaments would rupture (Figure 17).

The " step-like " deformity is generally conspicuous and like that at the sternal end is easy to reduce but more difficult to keep reduced. Recent dislocations if treated vigorously and sufficiently long from the start give good results while old or improperly treated cases are difficult to manage and may require operative fixation.

There are four varieties of dislocation, namely, upward, forward, subacromial and subcoracoid. The upward has already been described. The forward dislocation occurs but seldom or on occurrence soon becomes an upward dislocation by muscle pull and limb weight. The subacromial type is rare. Stimson[114] has reviewed the reported cases and the deformity produced is more pronounced than in other varieties due to the prominence of the acromion, upward displacement of the shoulder and the downward slope of the outer clavicle. The subcoracoid type is unusual and is generally complicated by fracture.

The capsular ligament and infra-clavicular ligaments may be partially or completely torn and interposition of the capsular ligament or fibres of the trapezius muscle may be interposed between the acromion and clavicle particularly in old cases and make closed reduction impossible. " Foot-ball shoulder " is a term often applied to upward dislocation of the acromial end due to its frequent occurrence in athletes from falls on the hand, elbow or shoulder and " tackling."

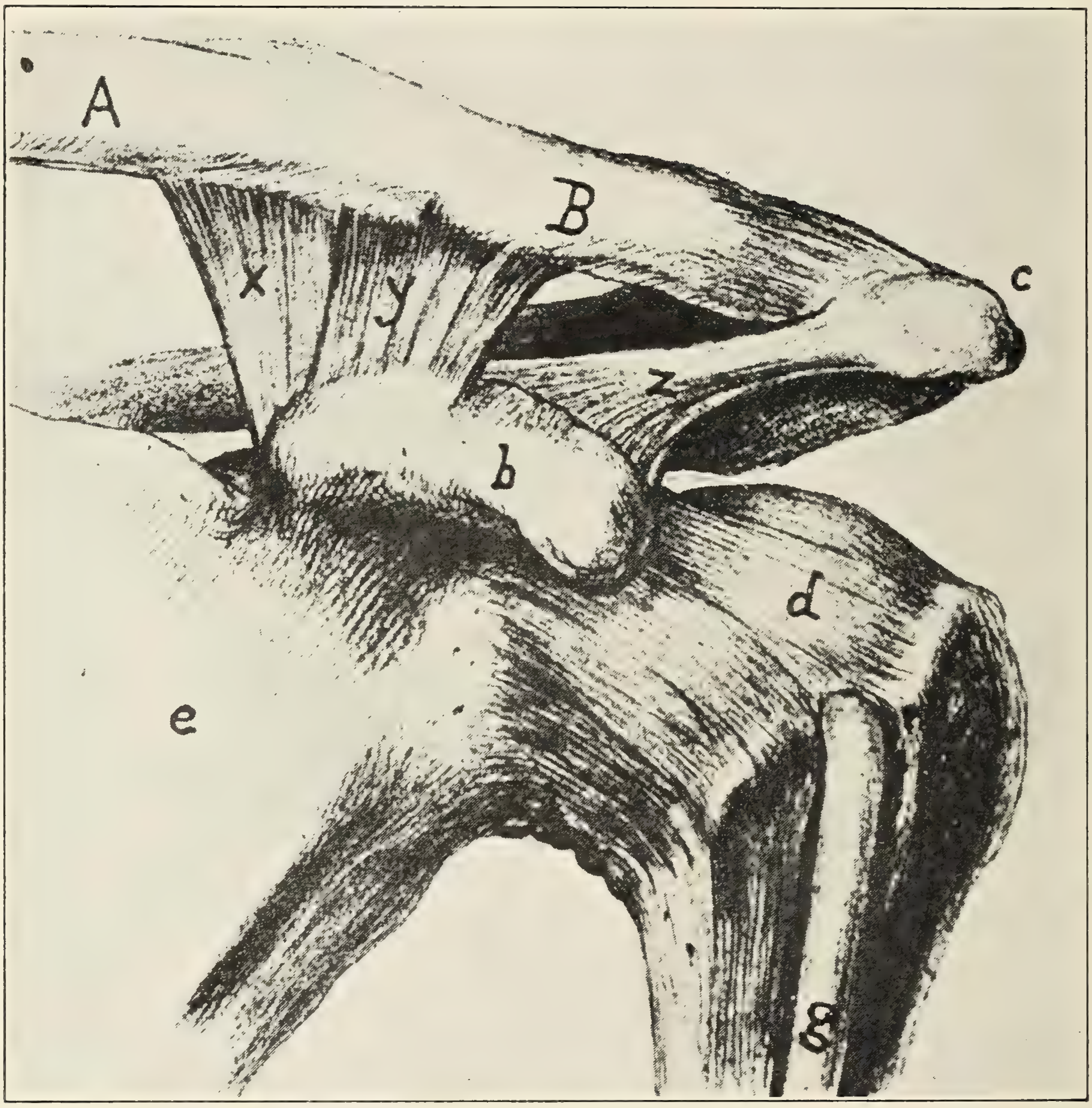


FIGURE 17. Ligaments of the outer end of clavicle.

B. acrominal end of clavicle.	*x.* conoid ligament.
b. coracoid process.	*y.* trapezoid ligament.
c. acromion process.	*z.* coraco-acromial ligament.

Subluxation is to be treated as a dislocation (luxation). VOL. I. 729.

REDUCTION

Upward dislocation. The upper arm is grasped and raised upward while pressure is placed on the outer end of the clavicle. It may be necessary to carry the shoulder and scapula back and outward.

Forward dislocation. Grasp the upper arm and with or without a roll in the axilla carry the shoulder outward, press posteriorly on the acromial end of the clavicle and at the same time carry both the shoulder and clavicle backward and outward.

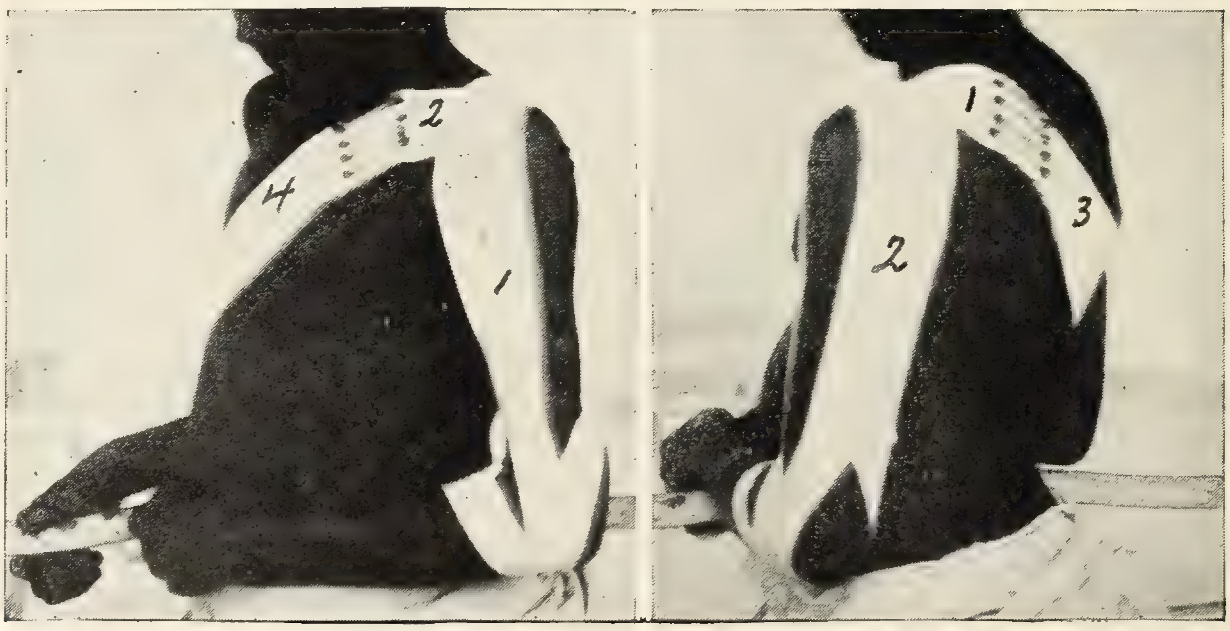
Subacromial dislocation. If of the right shoulder, stand at the right and a little behind patient, grasp the upper arm firmly with the right hand and strongly draw the shoulder upward, backward and outward while pressing downward and forward with the heel of the left hand passed over the patient's shoulder. Leriche,[58] being dissatisfied with suturing, found on reducing a case beneath the fluoroscope that reduction was maintained best when the arm was held horizontal or more than abducted. He immobilized the extremity in this position (as in a plaster aeroplane splint) for 21 days and obtained an excellent result.

Subcoracoid dislocation. This is reduced in a manner similar to that of a subacromial dislocation but is usually more difficult. Anaesthesia is necessary when the clavicle may be grasped by the hooked fingers and pulled forward.

IMMOBILIZATION

Upward dislocations may recur immediately after reduction once the arm is released and its weight permitted to drag on the joint. It is therefore obvious that slings, pressure pads, strapping and Velpeau dressings as usually applied, are useless. The Sayre adhesive dressing with a strap carried across the joint and anteriorly upon the chest is frequently efficient as Cotton[108] has pointed out but rarely tolerated by the patient for any great length of time. Cotton uses a figure of eight bandage with its crossed center over the dislocated end, one loop under the opposite axilla and the second passed under the elbow at right angle flexion to support the weight of the arm. Stimson[114] carries the forearm across the chest with the elbow in the axillary line and a long adhesive strap applied to the posterior cervical region, outer clavicle, anterior aspect of shoulder, across, under and behind the upper forearm to the shoulder posteriorly, over the dislocated end and thence to the sternum.

The most effective dressing the authors know of is one devised by the senior author. It is as follows: Four strips of ZO adhesive plaster are cut 3 in. wide and 18 in. long. One end of each strip is turned back upon itself on the adhesive side for 2 in., thus putting a short facing on the strip. Common shoe-top hooks are now inserted one-half in. apart along the edge and clamped down with a special clamp. The dressing is then applied as shown in the illustration (Figures 18, 19). The first strip (No. 1) is split at its free end and applied along the front of the arm, the split ends being carried around the upper forearm, which is flexed at right angles to the arm. The other end is carried over a "bunion" plaster placed over the acromio-clavicular joint and directed across the back toward the opposite axilla. A similar strip (No. 2) is applied posteriorly to the arm, is crossed over the acromio-clavicular joint, and then directed across the chest, toward the opposite axilla. Strip No. 3 passes from the posterior aspect of the sound axilla toward the hook-end of No. 1 strip, stopping short of it, however, by 2 in. Strip No. 4 is similarly applied. The two separate double sets of hooks are now interlaced with ordinary rubber bands, the amount of traction being entirely dependent upon the size and tension of the bands employed. The rows of hooks are placed 2 in. or more apart to allow for subsequent approximation due to slip and stretch. A small piece of gauze is placed beneath the hooks and elastics. The arm should be slung at the wrist. This dressing stays in place, is comfortable, holds the joint in reduction, and does not require frequent changing.



FIGURES 18–19. Author's dressing for dislocations, outer end of clavicle.

This same idea may be carried out somewhat differently. The loop of the adhesive strap does not pass under the olecranon but does pass under the ulna, with a pad so placed as to take the pressure from the sharp border of the bone. VOL. I. 729.

DISLOCATIONS OF THE STERNAL END

These are less common than those of the outer end but like them are prone to recur after reduction and become difficult to treat if not properly immobilized after early reduction. More often than not the dislocation is incomplete except in the rare post-sternal luxations. Dislocation may occur in any direction, upward, forward and downward, forward or retro-sternally. Recent dislocations are easily reduced with or without anaesthesia as a rule, by the recumbent position, manipulation outward and backward of the shoulder joint and with traction or pressure on the inner clavicle.

The displaced head may encroach upon vessels as they enter the mediastinum and Slaughter has reported a case with pressure on the trachea and a sensation of choking that required open reduction.

IMMOBILIZATION

The placing of a pad and adhesive strap over the dislocated sternal end of the reduced dislocation is only of value when the upper arm and shoulder joint are secured in a position that maintains the clavicle and its outer end as well, in a position favoring healing of the affected ligaments while preventing recurrence.

A Velpeau bandage, Desault dressing or triangular sling with the first strap of Sayre's dressing (in retro-sternal cases, to carry the shoulder back and the sternal end forward) or a sling and Lund swathe are generally sufficient in the simple cases to maintain reduction. After reduction the arm and shoulder should be placed in the position that prevents recurrence and then a dressing applied that maintains the shoulder arm and forearm in this position. Bed treatment, with a sandbag between the shoulders, or on a board beneath the mattress, depending upon the individual case, and a sandbag across the sternum and chest may be found advisable. Immobilization should be continued for 3–4 weeks and no heavy manual labor indulged in for an additional 3 weeks.

Dislocation of both ends of the clavicle is extremely rare and generally due to a crushing trauma in which both shoulders are compressed forward and inwards. The treatment is a combination of that as outlined above.

Bilateral dislocation of both clavicles. Dubs[79] reports a case of bilateral dislocation of the sternal ends of both clavicles. He treated the case by securing both elbows to each other, anteriorly, upon the chest.

VOL. I. 729.

OPERATIVE REDUCTION

Open reduction may be required of long standing or recurrent dislocations of either end of the clavicle, likewise in recent dislocations that are irreducible or only partially so by the interposition of capsular tissue, ligaments or muscle. Local or general anaesthesia may be used, a longitudinal or curved incision is made over the affected end, the interposing structures displaced and fixation made by kangaroo tendon passed through drill holes or the use of fascia lata. Silver wire, due to the superficial location of the joint is prone to cause suppuration as a foreign body and result in subsequent removal. Surgical repair of the torn infra-clavicular ligament is difficult and usually unnecessary once accurate replacement and proper immobilization has been secured.

OSTEOMYELITIS

Osteomyelitis of the clavicle may occur following traumatic periostitis or compound fracture but is usually due to staphylococcus aureus carried by the blood stream from a distant point as from a furuncle, infected wound, middle ear infection or mastoiditis. When seen early, incision, osteotomy and drainage are required. Old cases or chronic osteomyelitis with sequestra require sequestrectomy. The clavicle may be excised if extensive necrosis is present. The prognosis of these cases depends upon the underlying cause. When due to a local traumatic infection it is good. When due to a systemic blood stream infection the prognosis will depend upon the septicemia with its attending complications and not upon the local bone lesion.

Tuberculous osteomyelitis of the clavicle occurs but presents a less acute picture than osteomyelitis. It is more prone to begin at the epithyseal ends than in the diaphysis. The treatment is the same as that of other forms of osteomyelitis. Active therapy with the quartz light or direct sunlight are useful adjuvants.

Syphilitic gumma and yaws may involve the clavicle (French)[115] and undergo a secondary or mized infection (De Costa)[116] with resultant osteomyelitis and necrosis requiring drainage or sequestrectomy in addition to anti-syphilitic treatment. In connection with Yaws (Frambesia) one should remember that Arsphenamine treatment is even more effective against the Spirocheta Pertenue (Stevens)[117] than for the Spirocheta Pallida. Achard and Welter[36] have made a study of clavicular fractures in syphilitics.

Rudimentary or absence of clavicle may occur in congenital anomalies and in anostoplasia or cleidocranial dyostosis. In the latter condition there is generally impairment of bone growth causing moderate dwarfism and pronounced deformity in the formation of the membranous bones; the skull is rounded and broad, the face small and dentition delayed. The disease is often hereditary and surgical interference is seldom indicated. In the lion and tiger the clavicles are rudimentary and simply limit the range of abduction to which they adapt themselves.

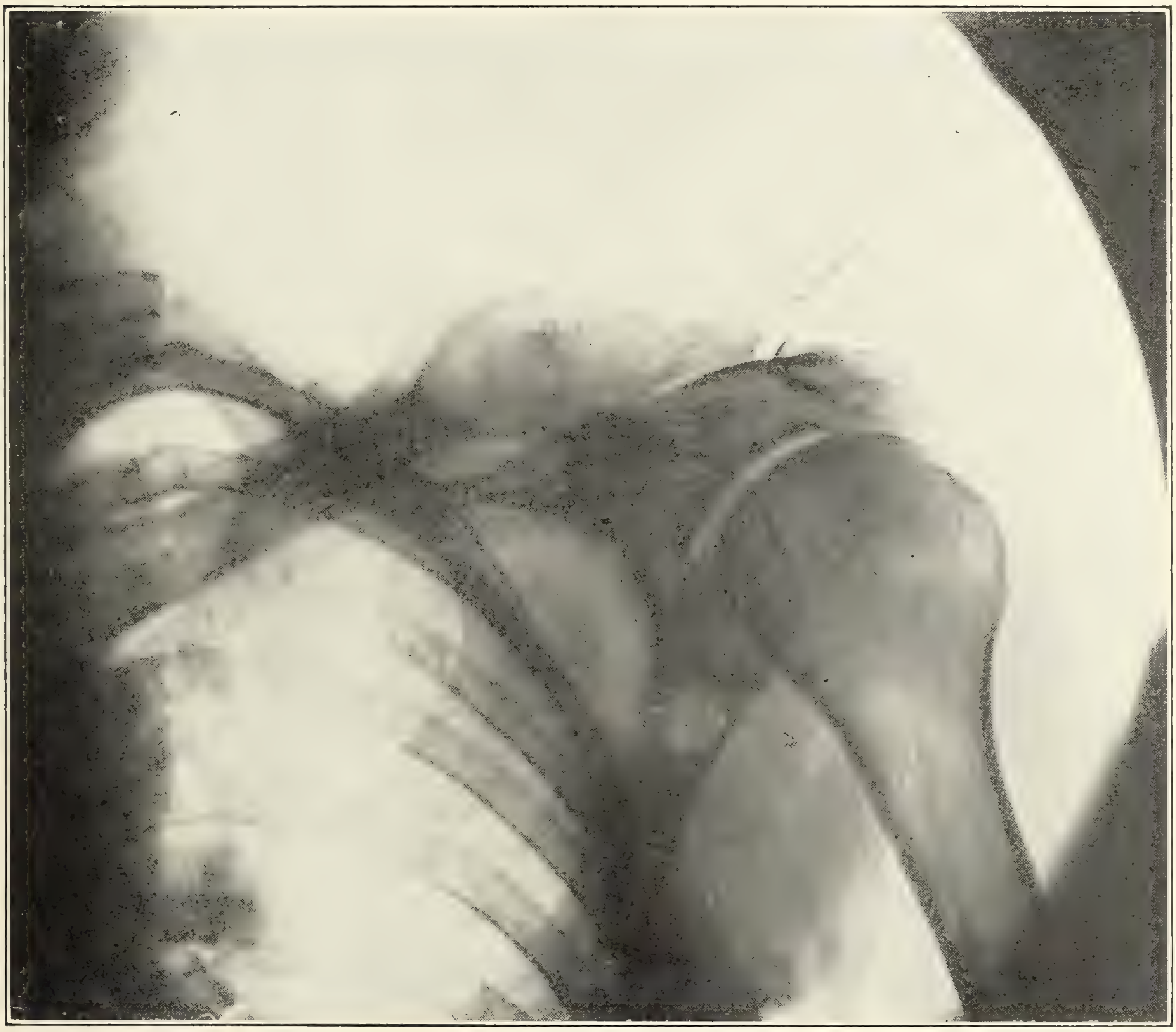


FIGURE 20. Sarcoma of outer end of clavicle.

Tumors of the clavicle. Malignant tumors of the clavicle may be primary or secondary but the first seems to be most common. In comparison with other bones of the upper extremity it ranks second to the upper end of the humerus though Christensen[120] found in 97 cases of malignant disease of the upper extremity that the order of frequency was:

Proximal end of humerus, 59 cases, scapula, 24 cases and clavicle, 14 cases. Malignant osteogenic tumors occurred in 9, giant celled tumor in 2 and endosteal endothelioma in 3 of the 14 cases.

The most common form of primary malignant disease of the clavicle is a periosteal fibrosarcoma involving more commonly the outer half or two-thirds (Figure 20).

Coley[121] states that out of over 275 cases of sarcoma of the long bones which he has personally observed, sarcoma of the clavicle has only occurred 16 times. In 11 of these cases trauma was a predisposing factor. He collected 64 cases and found that 30 occurred in the sternal end, 18 in the acromial end, 10 in the middle portion and 4 involved the whole bone. Myelomata have occasionally been observed in the bone, usually at the outer end. Lussana[103] describes two cases of sarcoma of the clavicle which were resected and cites 33 cases of malignancy collected by Norkus in

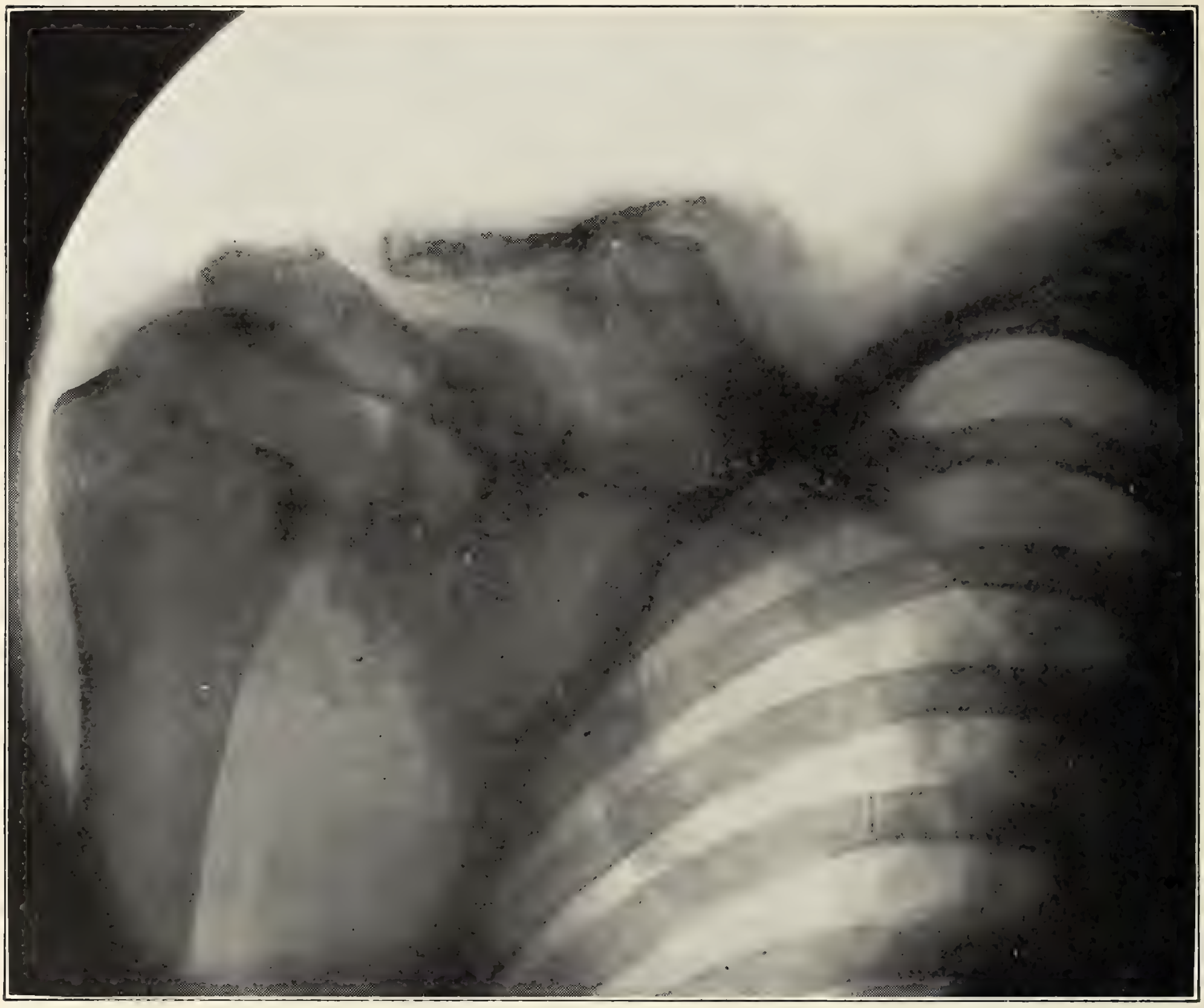


FIGURE 21. Spontaneous fracture in Sarcoma of clavicle with secondary necrosis. (See Figure 20).

1894 and of 147 malignant tumors collected by Angelletti in 1915. The best recent article on primary sarcoma of the clavicle is by Bell[77]. His case is still living, 3 years after excision. In reviewing the literature he finds that Coley (1910) reported 64 cases, 32 of these were reported by Norkes in 1893, 20 were culled from the literature and 12 were unreported cases. Again in 1920 Coley[121] added 32 cases found in print by Johansson and 3 cases under his own observation, 2 cases reported by Kalus and 5 of his own, making 106 cases up to 1920. Of the 64 cases collected in 1910, 3 were living after 50 years, 10 years and 5 years respectively. Since then 4 more cases treated by total excision plus Coley's mixed toxins of erysipelas and bacillus prodigiosus were reported as living. These were Delatour's case, 5 years, Coley's case, 3 years, Richardson's case, 5 years and Huntingdon's case 4½ years. Of the 106 cases reviewed by Coley only 7 cases are living from 3 to 50 years.

Waring[122] points out that in the case of malignant tumors of bone secondary to a primary malignant affection elsewhere, the tumor may exist in a bone for a considerable length of time without giving rise to either signs or symptoms which suggest its presence; and not infrequently the first evidence which manifests itself is the occurrence of a spontaneous fracture. Any patient with a so-called " spontaneous " fracture should be immediately X-rayed for a secondary growth and if found a search instituted for the primary focus.

Carcinoma of the clavicle is probably never primary (Delafield and Prudden)[118] but secondary to carcinoma in some other part of the body, usually the breast.

Treatment of malignancy of the clavicle. When the malignant disease is considered to be primary and early, total extirpation or resection of the clavicle and the excision of the neighboring lymph glands may totally efface the condition. Radiation should follow operation and not precede or take its place. When the disease is advanced or secondary to a process elsewhere, neither surgery nor radiotherapy is of any value.

Excision and resection of the clavicle. Excision of the clavicle is a serious operation because of the close proximity of this bone to the large vessels of the neck, their tributaries and the cords of the brachial plexus. Behind and below the bone lie the innomniate subclavicular and jugular veins; the subclavicular, suprascapular and internal mammary arteries; the cords of the brachial plexus; the pneumogastric nerve, and the thoracic duct. The veins particularly lying so close to the bone are prone to become involved by the disease and require excision (Figure 22).

Excision may be required for caries, necrosis, gunshot-wound, tumor, as a preliminary to ligation of the subclavian artery and vein in certain cases of amputation at the shoulder joint, or in cases requiring complete removal of the entire upper extremity for malignancy or trauma. Lussana in a study of tumors of the clavicle collected the cases of extirpations of clavicles in the literature and records, 12 cases by Richet et D'Esprey, 74 collected cases of Norkus (1894) of which 31 were for caries and necrosis and 33 for malignancy and 147 collected cases of malignant tumors, Angelletti (1915) in 65 cases of which operation had been performed. Lussana resected 2 clavicles for sarcoma.

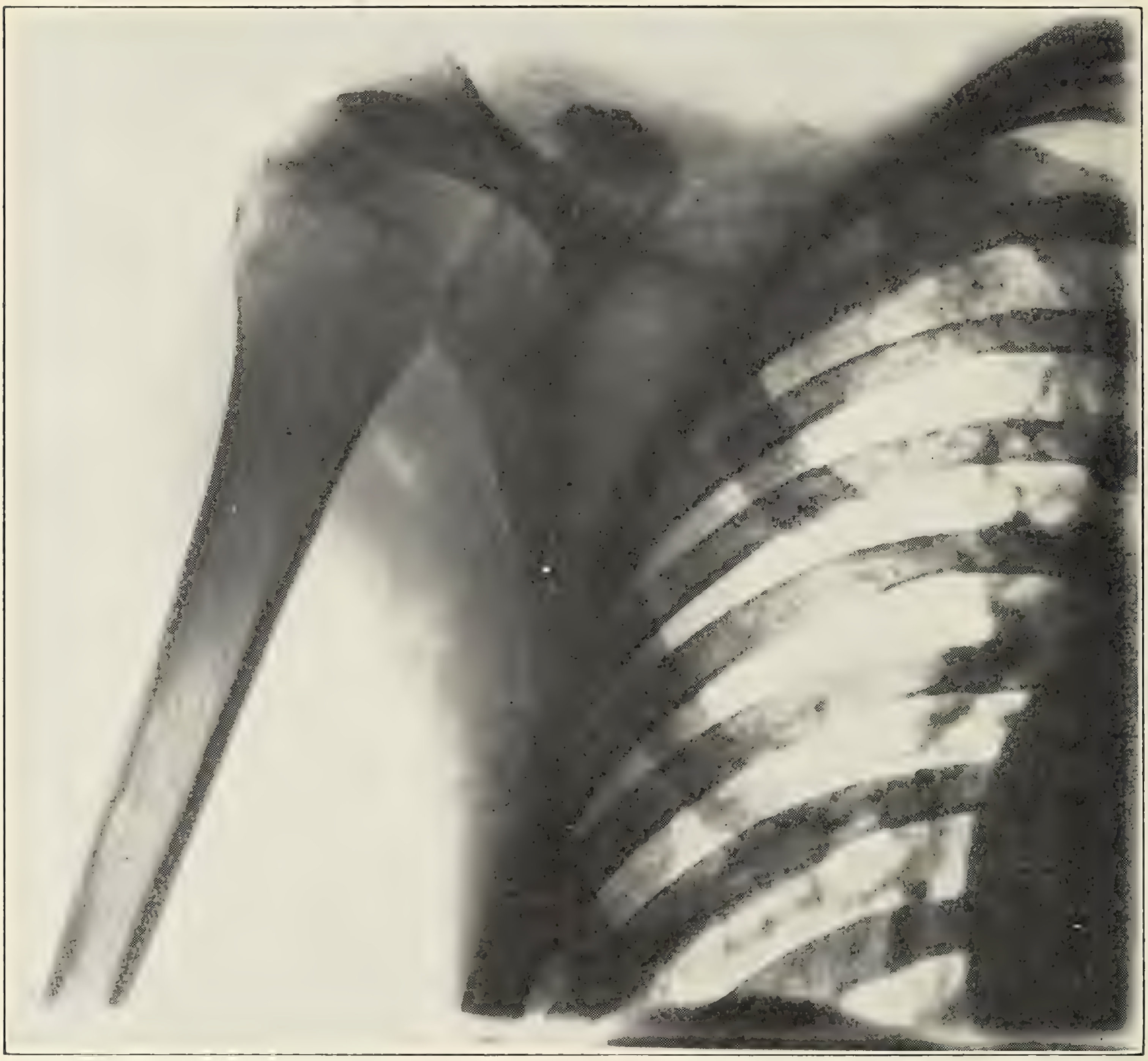


FIGURE 22. Excision of clavicle for sarcoma and necrosis. Same case as Figure 21. See also Figure 3 for excision in a case of a badly shattered, compound fracture of the clavicle.

Method of Operation. With the patient flat on his back, shoulders elevated and head turned to the opposite side, an incision is made down to the bone, through the periosteum from the sterno-clavicular joint to the acromio-clavicular articulation. The periosteum is elevated, the muscular and ligamentous attachments reflected and the clavicle removed. It may be advisable to saw the bone in one or two places (Warbasse)[119] and remove each fragment separately. The wound edges are sutured, drainage instituted if required and the limb put up in a Velpeau bandage. Absence of the clavicle causes the shoulder to droop downward and forward with some limitation of power but fairly good function results.

In conditions requiring excision of the clavicle it is to be remembered that function is not impaired to the degree that is first considered. Mainly, abduction is lost. Many animals without a clavicle get along perfectly well. It is lacking in hoofed animals who possess antero-posterior movements of the forward or upper extremities but no abduction (Davis). The clavicle is well formed in man, apes, bats, rodents and insectivora. In the carnivora, as the lion and tiger, it is rudimentary, whereas in the whale and seal it is absent. In the common fowl and birds, however, where the function of abduction is all important, we find the clavicle present (and joint forming the wish bone) and also a precoracoid bone formed by the coracoid process which is enlarged and continued forward to articulate with the sternum, making thus, in flying animals, practically *two* clavicles on *each* side.

History seems hazy (Bell) on the subject of priority of resection of the clavicle for sarcoma. The following pioneers are known: Reunner 1732, Mereau and D. Augerville of Paris in 1765, McCreary of Kentucky in 1811, Meyer in 1823 and V. Motl in 1828.

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SURGERY OF THE HAND

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SURGERY OF THE HAND

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Table of Contents

Surgery of the Hand 1162
  Introduction 1162
  Anatomy 1162
    The finger end 1163
    The flexor tendons 1163
    Extensor tendons 1166
    Synovial sheaths 1166
    Fascial spaces 1167
    The forearm 1169
    The nerves of the hand 1169
  Infections of the Hand 1170
    Infections about the nail 1170
    Anterior closed space infections 1172
    Carbuncles 1176
    Tendon sheath infections 1177
    Abscess of the middle palmar space 1185
    Abscess of the thenar space 1188
    Infections of the extensor tendon sheaths 1190
    Phlegmonous lymphangitis 1190
  Wounds of Tendons of the Hand 1195
    Flexor tendons 1199
    Extensor tendons 1210
Common Injuries of the Hand 1211
    The finger end 1211
    Lacerations 1211
The Nerves of the Hand 1215
Reconstruction Surgery of the Hand 1218
Dupuytren's Contraction of the Palmar Fascia 1229
    Treatment 1231
Congenital Malformations 1233
    Supernumerary digits 1233
    Macrodactylia 1233
    Syndactylism 1235

SURGERY OF THE HAND

INTRODUCTION

The great importance of the hand in its relationship to the human economy cannot be denied. Yet, it is an astonishing fact that the general problems relating to the surgery of the hand are either little understood or unduly minimized by the average surgeon. I believe the cause for this fairly general attitude is threefold. In the first place, in this era of major surgery of the abdomen, thorax, etc., the hand pales into insignificance. It is a subject of minor importance. Secondly, there is a widespread lack of knowledge of the more detailed intrinsic anatomy of the hand and, lastly, most surgeons are unwilling to assume the personal burden of all the minute details necessary for obtaining maximum results. I cannot over-emphasize the importance of a clear conception of the anatomy of the hand. One simply cannot hope to obtain good results in the treatment of hand infections, for instance, unless behind it lies a knowledge of the various fascial and synovial spaces, blood vessel and nerve distribution, joint conformations and tendon anatomy.

Linked closely with the anatomy goes the physiology of the hand, that delicate muscle balance between extensors and flexors, the reaction of tendons and sheaths to injury and inflammation and the coördinated finer movements of the different component parts. There is one more point to be emphasized. Here, as nowhere else in the field of surgery, does it become necessary for the surgeon himself to attend to the details of all the postoperative care if a happy outcome is to be expected. Relegating the postoperative treatment to assistants or house officers should be avoided.

In the present article, it is my desire to present the major problems in hand surgery, pointing out important aspects in the anatomy, emphasizing the necessity and means of accurate early diagnosis in infections and recording methods of treatment as developed through personal experience. For the more extended and detailed study of infections of the hand, the reader is referred to Kanavel's brilliant contribution on that subject.

ANATOMY

The hand is a remarkable complex mechanism capable of a variety of functions ranging from finely balanced delicate coördination to grossly crude movements. The skin of the palmar aspect is of finer texture than that on the dorsum. It is soft and pliant and abundantly supplied with tactile buds (Pacinian bodies) which are concentrated mainly in the region of the finger tips. It is for this reason that one should avoid making incisions over the front of the finger ends. The resulting scar is apt to be painful. The histology of the dorsum of the hand is noteworthy in that here are found numerous sweat glands, hair follicles, sebaceous glands, and columns of fat called colummæ adiposæ. The hair distribution extends sometimes to the middle phalanges. The peculiar histological structure of the skin on the dorsum accounts for the carbuncular infections frequently seen in this situation.

The finger end. (See Figures 1, 2, 3.) The translucent part of the nail is the body of the nail. Proximal to it is the lunula, behind which is the nail root. Beneath the body of the nail is the nail bed, while subjacent to the root is the nail matrix. Below the matrix and bed is the subungual space. Overlying the nail root, is the eponychium which is skin and reflected epithelium and is continuous on each side with the paronychium. The distal phalanx lies toward the back of the finger close to the nail matrix. Anterior to the phalanx is the anterior closed space composed of numerous compartments separated from one another by strong strands of connective tissue running from the corium in front to the periosteum and then by the so-called Sharpey's fibres into the phalanx. The small pockets contain fat, connective tissue, blood vessels and sweat glands. The digital vessels run slightly anterior to the phalanx. Figure 2. It is important to remember that the distal flexion crease marks the distal joint cavity and the distal end of the flexor tendon sheath. Therefor, incisions for finger-end infections should always fall short of this landmark. (Figure 3.)

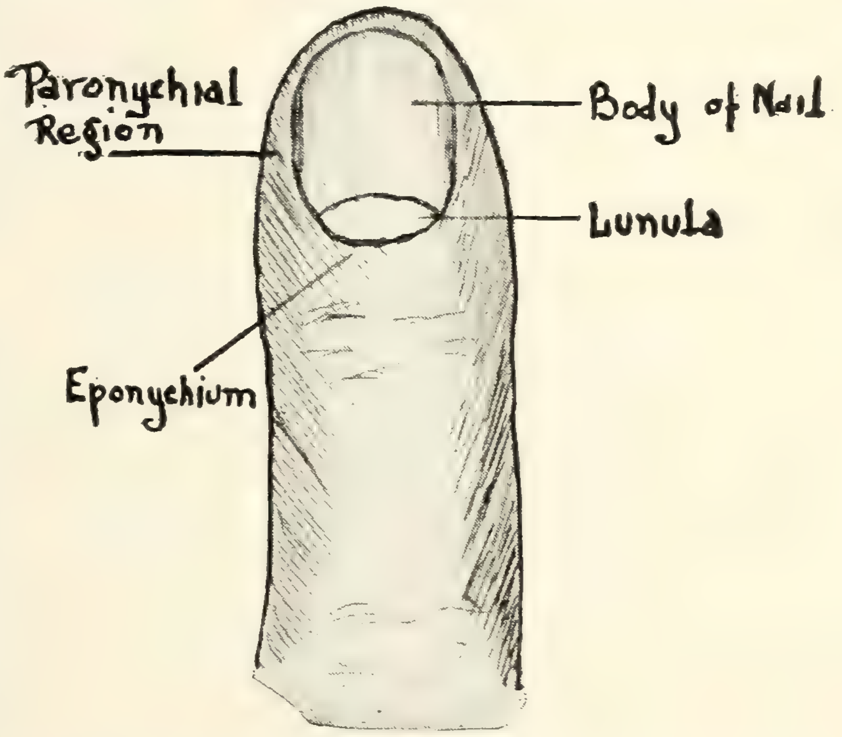

Figure 1. Drawing of the finger end. Beneath the body of the nail is the nail bed. Beneath the eponychium is the nail root subjacent to which is the nail matrix. Below the matrix and bed is the subungal space.

The flexor tendons. At the wrist, the flexor tendons pass into the hand through an osseo-aponeurotic canal in company with the median nerve and the radial and ulnar bursæ. This canal, bounded in front by the anterior annular ligament, and laterally and posteriorly by the carpus and wrist is practically a non-distensible space. The contained structures must bear great pressure here in the presence of infection with its accompanying swelling and edema, as in radial or ulnar bursitis. This anatomical detail clarifies the rationale of splitting the anterior annular ligament, especially for ulnar bursitis. As they pass through, the sublimis tendons to the middle and ring fingers lie most superficially, those to the little and index fingers next and the profundus tendons deepest. The median nerve lies most superficial, an important point in injuries at the wrist. For the same reason, one must not forget that the ulnar nerve passes in front of the annular ligament to the outer side of the pisiform bone and is covered only by skin and fascia.

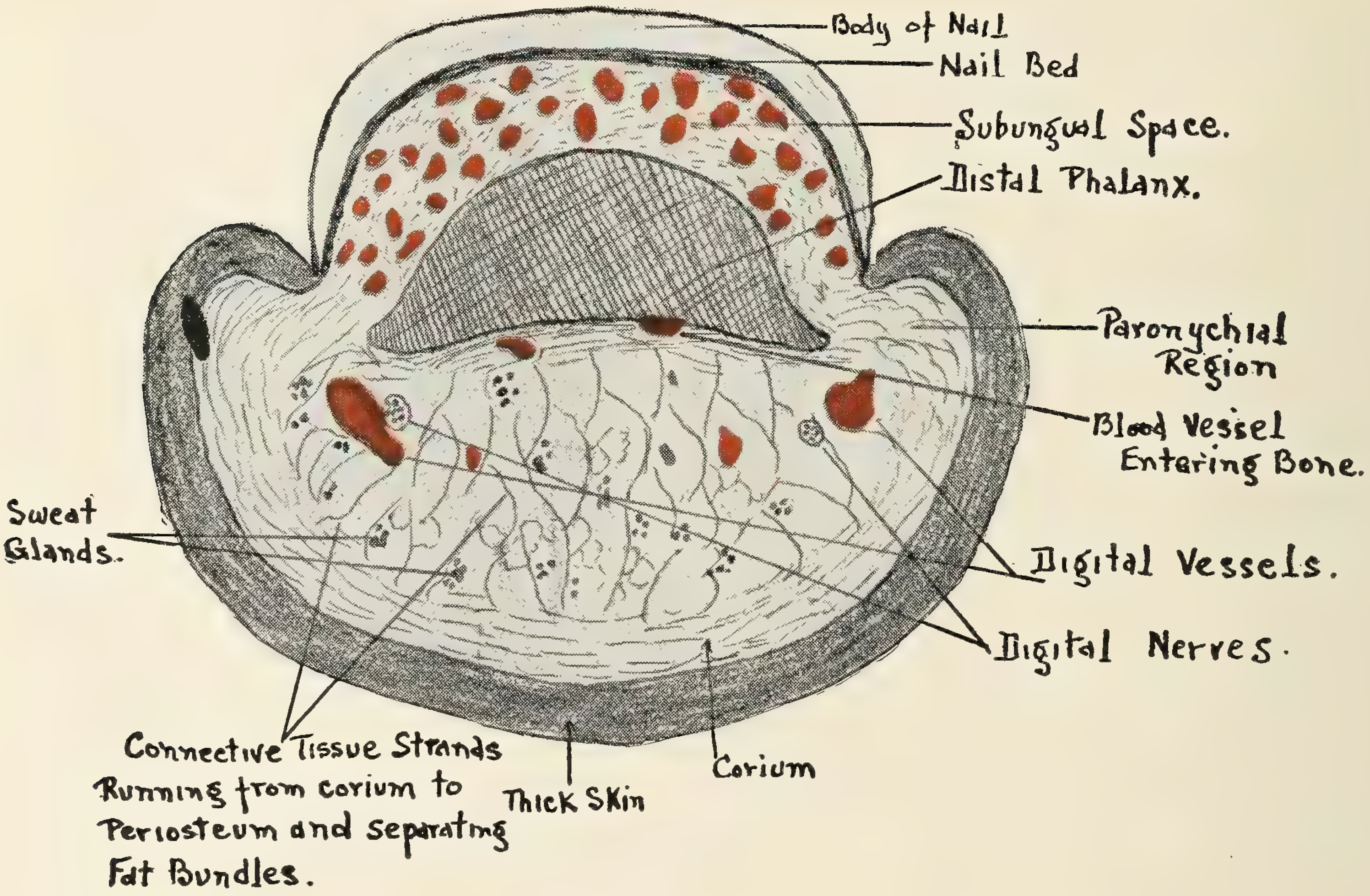

FIGURE 2. Drawing of a photomicrograph taken from a cross section through the middle of the distal phalanx. It will be noted that the distal phalanx is near the dorsum. The subungal space contains an extensive capillary network. Attention is called to the strong connective tissue strands running from the corium to the periosteum and separating the fat bundles into compartments. In the section is seen a vessel entering the anterior surface of the phalanx. These vessels are of importance in some of the cases with osteomyelitis of the distal phalanx.

On leaving the wrist, the flexor tendons spread out beneath the palmar fascia, each to go to its respective finger. At a point corresponding to the distal flexion crease of the palm, each flexor sublimis tendon divides in two to allow its corresponding profundus tendon to pass through it

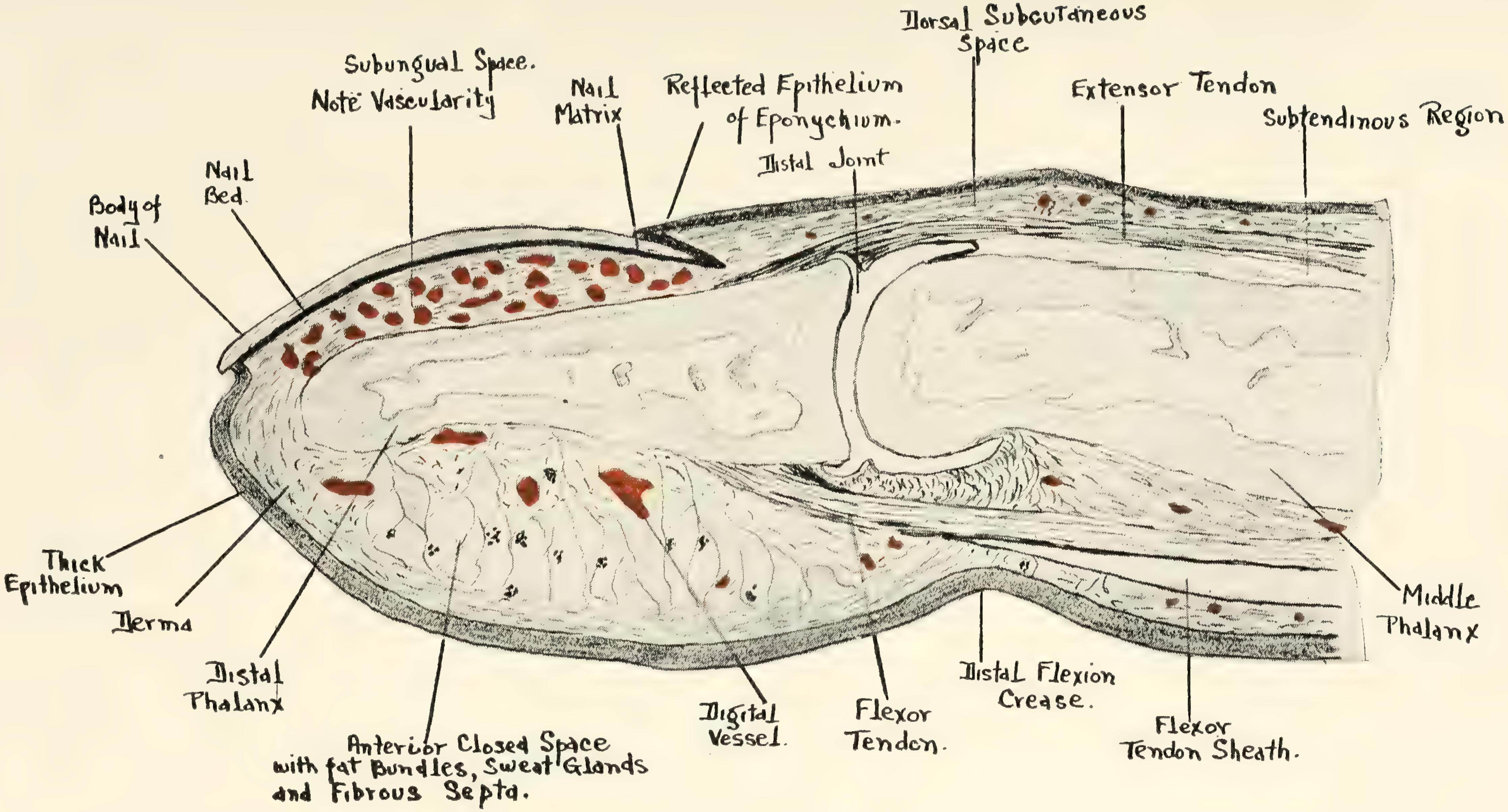

FIGURE 3. Drawing of a photomicrograph taken from a longitudinal section through the center of the finger. The reflected epithelium of the eponychium becomes continuous with the nail matrix. The importance of the flexion crease is here shown. It will be seen that the flexor tendon sheath is practically beneath the skin at this point. Because of this anatomical fact, wounds in the region of the flexion creases assume serious proportions from the standpoint of tendon sheath infection.

from a deep position to lie in front. From this point the profundus tendon lies most superficial up to its insertion into the base of the distal phalanx. Opposite the distal end of the proximal phalanx, each sublimis tendon divides into two slips which are inserted into the lateral aspects of the middle phalanx at about its mid-point. After leaving the palm, both tendons pass into the finger through an osseo-aponeurotic canal, composed of strong fibrous tissue in front and laterally and the phalanges posteriorly. This fibrous structure prevents bow-stringing of the tendons during flexion. Over the bodies of the proximal and middle phalanges, this ligament is well pronounced and strong, while over the joints it is much thinner. The surfaces of the tendons and the enveloping canals are lined by a most delicate layer of endothelium. The slightest trauma to this layer causes considerable reaction, a point to be remembered when dealing with the operative treatment of infections and injuries. The tendons derive their blood supply through a mesotenon or mesentery-like structure called vincula tendineæ. There are two sets: (*a*) the ligamenta brevia, two in each finger, tiny bands covered with endothelium which connect the tendon of the flexor sublimis to the front of the proximal and distal interphalangeal joints respectively, and (*b*) the ligamenta longa which connect the under surface of the flexor profundus to the subjacent flexor sublimis tendon. These are of importance in the treatment of tendon injuries.

Extensor tendons. The anatomical details of the extensor tendons are simple and require no description here other than the fact that *there are no synovial sheaths* on the dorsum of the fingers. The only place where the extensor tendons have tendon sheaths is beneath the posterior annular ligament. They are about two inches in length and extend one-half inch proximal and one inch distal to the posterior annular ligament. The tendons of the extensor communis digitorum have a common sheath, while all the other dorsal tendons have individual sheaths in this situation.

Synovial sheaths. (See Figure 8.) It is essential to have a clear conception of the various synovial sheaths and fascial spaces of the hand before one can attempt the diagnosis and treatment of the more severe hand infections. Without such knowledge it is impossible to visualize what pathological conditions can exist and what their paths of extension may be. The synovial sheaths on the flexor surface are clear cut structures. Each finger has a flexor tendon sheath. It extends from the distal digital flexion crease to about the level of the proximal palmar flexion crease where it ends in the index, middle and ring fingers. The sheath of the flexor tendon of the thumb extends from the distal flexion crease and continues proximally between the two tendons of the flexor brevis pollicis. Practically always — and for clinical purposes it should be considered so —

this sheath becomes continuous with the radial bursa which passes beneath the annular ligament and comes to lie on the pronator quadratus muscle two inches above the ligament. The sheath of the little finger tendons proceeds as do the sheaths of the other fingers, but instead of ending in the palm, it becomes continuous, nearly always, with the ulnar bursa which passes beneath the annular ligament and ends two inches above it upon the pronator quadratus muscle. The ulnar bursa is larger than the radial bursa. They lie in close apposition beneath the annular ligament. More often than not they communicate with one another. It is important to remember this in the interpretation of clinical signs for infections. The flexor tendons of the fingers are projected, as it were, into the ulnar bursa from the outer side; i. e., they are not entirely surrounded by this synovial sac.

One more point. Mention was already made of the fact that the tendon sheaths in the fingers are protected by strong fibrous tissue which is strongest over the phalanges where these thickenings are known as the vaginal ligaments, and is weakest over the joints. For this reason wounds over the front of the joints assume major importance. The danger of a tenosynovitis is evident.

Fascial spaces. Kanavel, by his serial cross-sections of the hand and his injection experiments, put the anatomy of the fascial spaces upon a clear, firm foundation. Upon the dorsum of the hand, there are two regions where pus can accumulate. Just beneath the skin and superficial to the extensor tendons is a rather ill-defined region, the dorsal subcutaneous space, which contains loose areolar tissue. This extends over the entire dorsum of the hand. I have seen this region infected frequently in policemen especially, who have hit someone in the mouth and received a laceration from the victim's teeth over one of the knuckles. These infections have usually been virulent. (See Figure 20.)

Beneath the extensor tendons and the tendinous aponeurosis of the tendons and superficial to the metacarpal bones and the fascia covering the interossei muscles is a well-defined fascial compartment, the dorsal subaponeurotic space. It extends distally to the region of the knuckles and proximally to the wrist. Laterally it fades off into the subcutaneous tissues. This region may become involved in compound fractures of the metacarpals, suppuration in a metacarpo-phalangeal joint, by direct implantation infection or after extension from an infection in the palm and web regions.

In the palm, the anatomy of the fascial spaces is intimately associated with the anatomy of the palmar fascia and its numerous ramifications. The fascial septa in the palm can be considered as prolongations of the palmar fascia, thereby simplifying the visualization of the various spaces. The key to the situation is the origin of the adductor transversus pollicis muscle from the front of the middle finger metacarpal bone. (See Figure 9.) This point marks the dividing line between the mid-palmar and thenar spaces. Overlying the anterior surface of this muscle is a firm fascial septum which actually separates the two spaces. To the ulnar side of it lies the middle palmar space which has the shape of a compressed inverted truncated cone. It is situated behind the flexor tendons and sheaths and lumbrical muscles and in front of the anterior surfaces of the metacarpal bones of the little and ring fingers and the fascia overlying the interossei muscles. More proximally in the hand it is overlain by the beginning of the ulnar bursa. Its distal broad extremity corresponds to an imaginary line connecting the inner end of the distal palmar flexion crease with the outer end of the proximal palmar flexion crease. Proximally at the wrist it fades off indefinitely into the fascial region just superficial to the pronator quadratus muscle and behind the radial and ulnar bursæ. It will be seen that infections of the flexor tendon sheaths of the little, ring and middle fingers and also of the ulnar bursa can extend into this space. Likewise, an infection of this space can occur in compound fractures of the fifth, fourth, or third metacarpals where there has been a tearing of the interossei muscles and the fascia overlying them anteriorly. I have seen this train of events in three instances. Pus in the mid-palmar space may extend distally along the lumbrical muscles of the little, ring and middle fingers, via the so-called lumbrical canals, (diverticula of the middle palmar space) and the digital vessels and nerves and come to lie in the web region between these digits.

The thenar space lies to the radial side of the third metacarpal and corresponds to the thenar eminence, although it is deeply placed in the hand. Its anterior boundary is the fascial septum that separates it from the middle palmar space. Its floor or posterior surface is the anterior aspect of the adductor transversus pollicis muscle. The flexor tendons of the index finger pass in front of it. This space, it can be seen, may be infected in compound fractures of the index metacarpal bone, by direct implantation, and by extension from an index finger or thumb tenosynovitis. Pus in the space itself can pass between the adductor transversus and obliquus pollicis muscles and come to lie behind the former, between it and the first dorsal interosseus whence it passes easily to the web between thumb and index finger. The inner limit of this space is marked on the surface of the hand by the adduction crease. Incidentally, there is no anatomical communication between the middle palmar and thenar spaces. I have never seen an extension of infection of one space into the other.

The forearm. There are a few points in the anatomy of the forearm which need emphasis, inasmuch as they are of importance in the treatment of infections extending upward from the hand. It will be recalled that the proximal ends of the radial and ulnar bursæ terminate in the region of the pronator quadratus behind the flexor tendons and that the upper limits of the thenar and middle palmar spaces are situated in the same region. Accumulations of pus escaping from any of these structures come to lie first upon the pronator quadratus, in an area approximately two or three inches above the wrist. From this point, the origin of the flexor profundus digitorum and flexor longus pollicis muscles prevents the pus from passing behind these structures. The exudate must pass in front and does so, following intermuscular septa, especially between the flexor sublimis and the two deeper flexors, the profundus and the longus pollicis. Somewhat further up the forearm, the pus would lie between the flexor carpi ulnaris and the flexor profundus. At about this point, both the ulnar artery and the median nerve pass beneath the origin of the flexor sublimis. The median nerve passes through the pronator radii teres muscle up toward the ante-cubital fossa. Exudate may follow along either structure. If it follows the median nerve, it may reach the cubital fossa, a rather unusual clinical finding. If it follows the ulnar artery, it may proceed distally again under the flexor carpi ulnaris and come to lie subcutaneously two or three inches above the wrist on the ulnar side.

The nerves of the hand. (See Figure 33.) I cannot leave the subject of the anatomy of the hand without stressing the importance of the rôle played by the branches of the median and ulnar nerves in the various problems of hand surgery. In the operative treatment of the various infections, the incisions are so planned and executed as to avoid injury to any of the nerves. In traumatic wounds of the forearm, wrist or hand, no examination is complete without a careful check on the skin sensation of the hand and fingers and the patient's ability to abduct and adduct the fingers in the extended position. Only too often is a divided median or ulnar nerve missed because the physician has forgotten to look for anæsthesia or impairment of motion in the fingers. The same applies to wounds of the fingers with severance of digital nerves. Division of a digital nerve gives real finger disability, notably skin anæsthesia and volume atrophy and there is, therefor, a definite indication for operative repair as soon as the condition is diagnosed clinically. The operation, though tedious, has, in my hands, given practically uniformly excellent results. Bunnel recently called attention to this point in an excellent contribution.

The median nerve passes down the forearm between the flexor profundus and flexor sublimis muscles. Just above the annular ligament, it becomes more superficial, lying to the radial side or under the tendon of the palmaris longus. It then passes beneath the annular ligament into the hand where it lies just beneath the palmar fascia. At the distal edge of the annular ligament, it gives off a branch which supplies the abductor, opponens and superficial head of the flexor brevis pollicis muscles. This is a very important nerve in the hand. Attention will be called to it again in discussing tenosynovitis of the thumb. The remainder of the median nerve sends digital nerves to both sides of the thumb, index, and middle fingers and the radial side of the ring finger. In the hand, those nerves lie just beneath the digitations of the palmar fascia, while in the fingers they occupy an antero-lateral position, superficial to the digital arteries.

The ulnar nerve descends down the forearm along the ulnar side, lying upon the flexor profundus digitorum, its upper half being covered by the flexor carpi ulnaris, its lower half lying on the outer side of this muscle, being covered only by skin and fascia. The nerve lies to the inner side of the artery. It crosses anterior to the annular ligament and divides into two branches, the superficial palmar and deep palmar. The former sends two digital branches which supply the inner side of the ring finger and both sides of the little finger. The deep palmar branch follows the course of the deep palmar arch beneath the flexor tendons. It sends muscular branches to the muscles of the hypothenar eminence, the interossei and the two inner lumbricals, the adductors transversus and obliquus pollicis and the inner head of the flexor brevis pollicis. The outer two lumbricals are supplied by the median nerve.

INFECTIONS OF THE HAND

Infections about the nail. The eponychium or cuticle may be the site of an accumulation of pus, which lies between the surface skin and the reflected epithelium. This infection may be called an eponychia. (See Figure 4.) A small curvilinear incision near and parallel to the edge of the cuticle or, if the infection resembles a " pus blister," simply removal of its roof, brings about a rapid cure. Not infrequently, this infection extends deeper and pus accumulates beneath the base of the nail. The treatment noted above for eponychia fails to effect a cure. Pain and swelling persist. On close examination, it will be seen that the color of the lunula has changed to a greyish-yellow. Only radical removal of the nail base will bring about a cure and it does this rapidly. Hot moist dressings or a bland ointment help to relieve pain following this slight operation.

The paronychial tissues may become infected primarily or secondarily from an eponychial extension. Neglected hang-nail, manicure injuries, and pin pricks are the usual causes. A very frequently encountered infection is a tiny collection of pus in the paronychial region, rather deeply situated. The causative organism, usually the staphylococcus, must be of low-grade virulency because this tiny abscess may remain localized for a considerable time without any evidence of spreading. Superficially, there is little evidence of its existence, practically no swelling and little or no redness. On careful examination, a definite point of tenderness can be found with the end of a probe. A small incision at this point with a small sharp scalpel allows egress for the drop or two of pus and rapid healing in twenty-four to forty-eight hours follows.

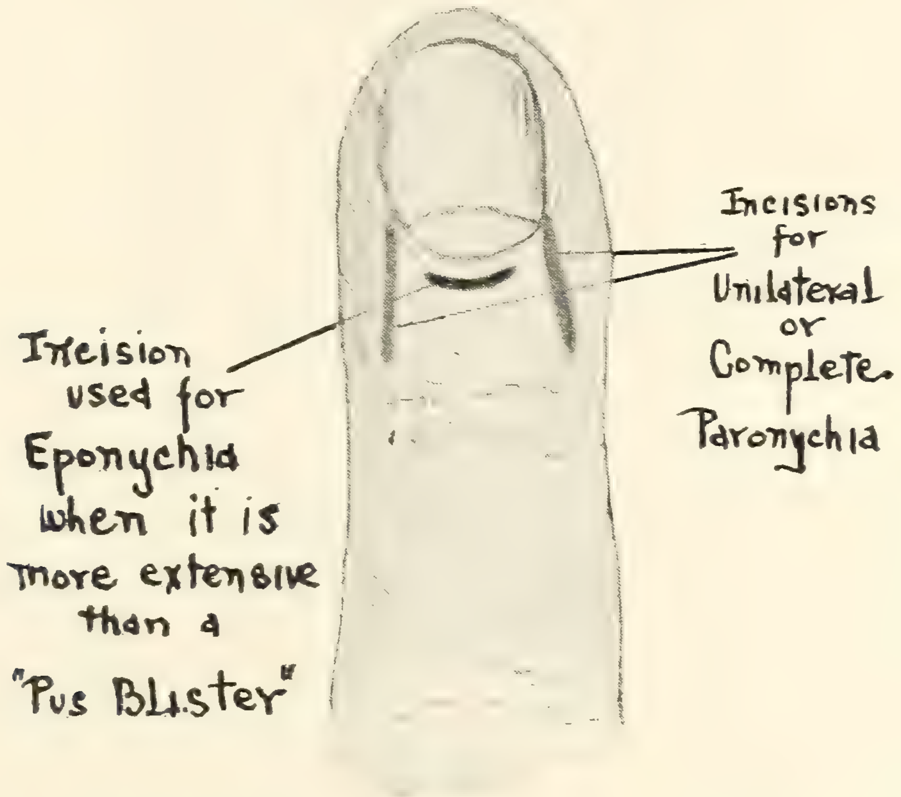
Incisions for Unilateral or Complete Paronychia
Incision used for Eponychia when it is more extensive than a "Pus Blister"

FIGURE 4. Drawing illustrating the incisions used for unilateral or complete paronychia. Great care must be exerted in making this incision to avoid injury to the nail bed so as to prevent a permanently split nail. The base of the nail must be removed after the eponychium is reflected, because it plays the role of a foreign body in an abscess cavity. The incision for eponychia is rarely necessary because this infection usually amounts to a pus blister. Removal of the roof of the blister is all that is needed.

Should the infection just described progress, it would tend to spread toward the nail. The pus accumulates *beneath* the base of the nail at a point proximal to the cuticle or eponychium. Such an infection would constitute a unilateral paronychia. As the process extends, the pus usually passes around the nail base to the opposite side still *beneath* the nail and involves the opposite paronychial region, forming a complete paronychia or "run-around." Pus may spread distally beneath the nail, lifting more of it from the nail bed. Upon examination, it will be seen that the paronychial and eponychial tissues are raised and reddened and quite tender. The subungual location of the pus has changed the color of the lunula to a yellowish-grey. Gentle pressure on the nail may indicate the presence of pus beneath. With the knowledge that the pathology of paronychia is an abscess beneath the nail with the nail projecting into it as a foreign body, the treatment becomes apparent, drainage of the abscess, and removal of the foreign body. Experience has shown that this can best be done by making a longitudinal incision along the outer side of the nail, going back about three-eighths of an inch. (See Figure 4.) Great care should be exercised to avoid injuring the nail bed so as to prevent a permanently split nail when it grows out anew. The eponychial flap thus produced is pushed off the nail and the nail base exposed. The point of a small sharp scissors is inserted beneath the detached edge of the nail which is then cut off with all of the base of the nail which has become separated from the matrix by the pus. If the infection has progressed to the opposite side, a similar incision is made here also and the entire base of the nail is removed. A small bit of vaseline gauze or rubber dam beneath the reflected eponychial flap and hot wet dressings for a day or two constitute the important postoperative care. Recovery following this radical treatment is rapid and its use is recommended in all cases of paronychia. The operation can be performed quickly and painlessly under digital nerve block and the surgeon knows that the infection is under control. I feel sure that the general adoption of this treatment will cut down the number of chronic, painful finger-end infections.

Anterior closed space infections. On the anterior aspect of the finger-end, a number of infections may occur. Although they are usually classified under different headings, they, separately, constitute a step in the progress of the infection and differ from one another in degree. Thus, the simplest form encountered is a " pus blister," caused by the spreading of pus beneath the epidermis. It is easily recognized and treatment consists in removal of all detached skin. This is a safe rule to follow in all " pus blisters " of the hand. The next common infection is the so-called " collar button abscess " which receives its name from the characteristic distribution of the pus. (See Figure 5.) A pin prick, a sliver of wood and the like, implants the infecting organism into the subdermal tissues or even deeper. A collection of pus forms, later rupturing through a sinus in the derma. A second collection or " pus blister " forms beneath the epidermis. Such abscesses form in other parts of the hand, especially where the skin is much thickened, as in the distal part of the palm. The superficial appearance of these abscesses resembles the ordinary " pus blister." On closer examination, however, it is found that there is a fairly wide area of surrounding redness and swelling with considerable induration at the point of maximum tenderness. The treatment consists in removing all detached epithelium covering the superficial pocket, identifying the sinus or sinuses leading to the deeper pocket and, with this as a center point,

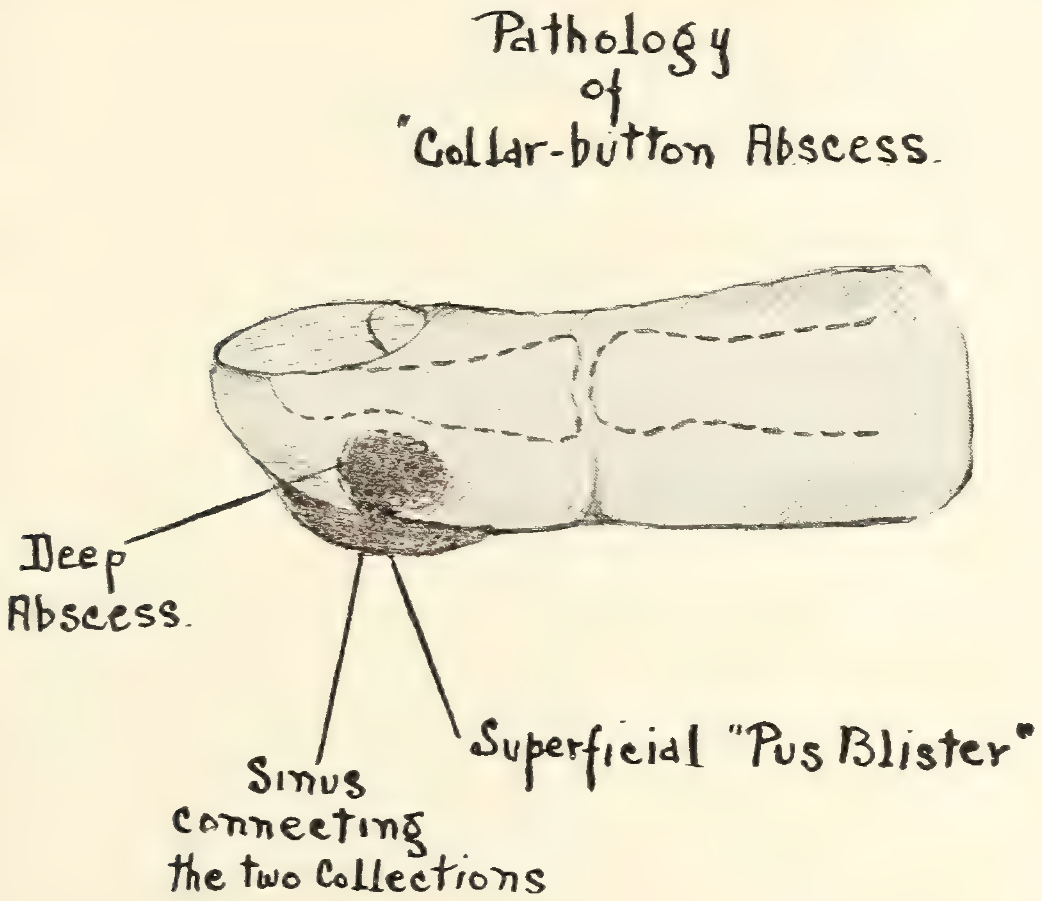

FIGURE 5. Drawing indicating the pathology of a collar button abscess. A similar lesion may be found elsewhere in the hand where hypertrophied epithelium exists, as in the distal part of a palm. It is important to recognize the existence of the sinus connecting the two pockets.

making either a linear or crucial incision large enough to adequately drain the deep collection.

Infections may involve part or the whole of the pulp end of a finger. They are known as anterior closed space abscesses or felons. The cause may be a trivial pin prick, or injury by a splinter. Very often, indeed, there is no history whatever of injury. The patient soon develops throbbing pain which prevents sleep. The end of the finger becomes swollen and tense. It is tender to touch, and, early in the disease, this tenderness is most pronounced over the site of injury. Objectively, in the early stages, one may find nothing more than a slight redness, a small area of tenderness and induration, and a very slight change in contour of the pulp. At this stage, an incision should be made, even though actual pus may not be seen, for the relief of tension hastens recovery and prevents bone involvement. Later on in the disease, the pulp becomes very tense and swollen. As necrosis takes place, the sensitiveness lessens. The speed with which bone involvement takes place is remarkable. It should be remembered that this part of the finger is really a closed space, anatomically. With infection, swelling occurs and pressure is produced upon the contained structures. In the great majority of instances, Kanavel's contention that the bone necrosis is due to shutting off of the blood supply of the diaphysis by the swelling and edema is probably true. This is strengthened by the fact that the epiphysis receives its blood supply before the digital vessels enter the anterior closed space and is practically never involved except in very late neglected cases. Not infrequently, however, one sees infections with necrosis of only a small part of the diaphysis, say, the tuft. It is hard to fit Kanavel's theory to this clinical finding. To explain it, one may assume that the infection enters the bone through one of the many nutrient foramina present in the distal phalanx. Should osteomyelitis occur, the time of sequestration will depend on the age of the patient. In children, up to the age of about eighteen, when the center of ossification unites with the diaphysis, sequestration of the shaft may be surprisingly rapid, often in a week. In adults, loose bone may be removed by the end of three and a half to four weeks. In this connection, it may be pointed out that, in children, one may fairly regularly expect regeneration of the diaphysis from the epiphysis after three or four months.

The incision recommended for felons is made on one side of the finger. (See Figure 6.) It avoids the tactile part of the pulp and the subsequent scar is painless. Complete thorough drainage is obtained by cutting across the connective tissue fibres that run diagonally from corium to periosteum. A small piece of thin rubber tissue or vaseline gauze is inserted for drainage. Hot saline or boric wet dressings, *elevation of the hand,* and sedatives bring comfort and quick recovery. In making incisions for localized collections anteriorly, one should scrupulously avoid the distal flexor crease for here the flexor sheath is practically just under the skin. An abscess in this region, therefor, assumes serious proportions and the prognosis should be guarded. The treatment of the osteomyelitis depends upon the extent of involvement. If the diaphysis stands out free and bare, it should be removed by a rongeur. If only a small area is found "bare," and x-ray discloses but little involvement, conservatism should be the rule. Healing very often takes place without further trouble. These operations can be performed under digital nerve block with a tourniquet about the base of the finger.

Not infrequently, even with appropriate and early treatment, the infection may be of such a nature as to cause the formation of connective tissue sloughs which are either extruded or picked out with forceps through the operative wound. As a rule, the loss of this small amount of pulp from the end of the finger leaves very little disfigurement and usually no disability. Occasionally, however, more is lost than usual. This leaves a finger end where the skin is adherent practically to bone. Ordinary pressure produces pain and a real disability ensues. To relieve the pain and, at the same time, restore the contour of the finger end, use may be made of a simple, yet effective, operation. This may safely be performed two to three months following healing of the wound. Through an incision on the side, the skin and whatever is left of the subcutaneous tissues are dissected away from the bone with a very small sharp knife. A piece of

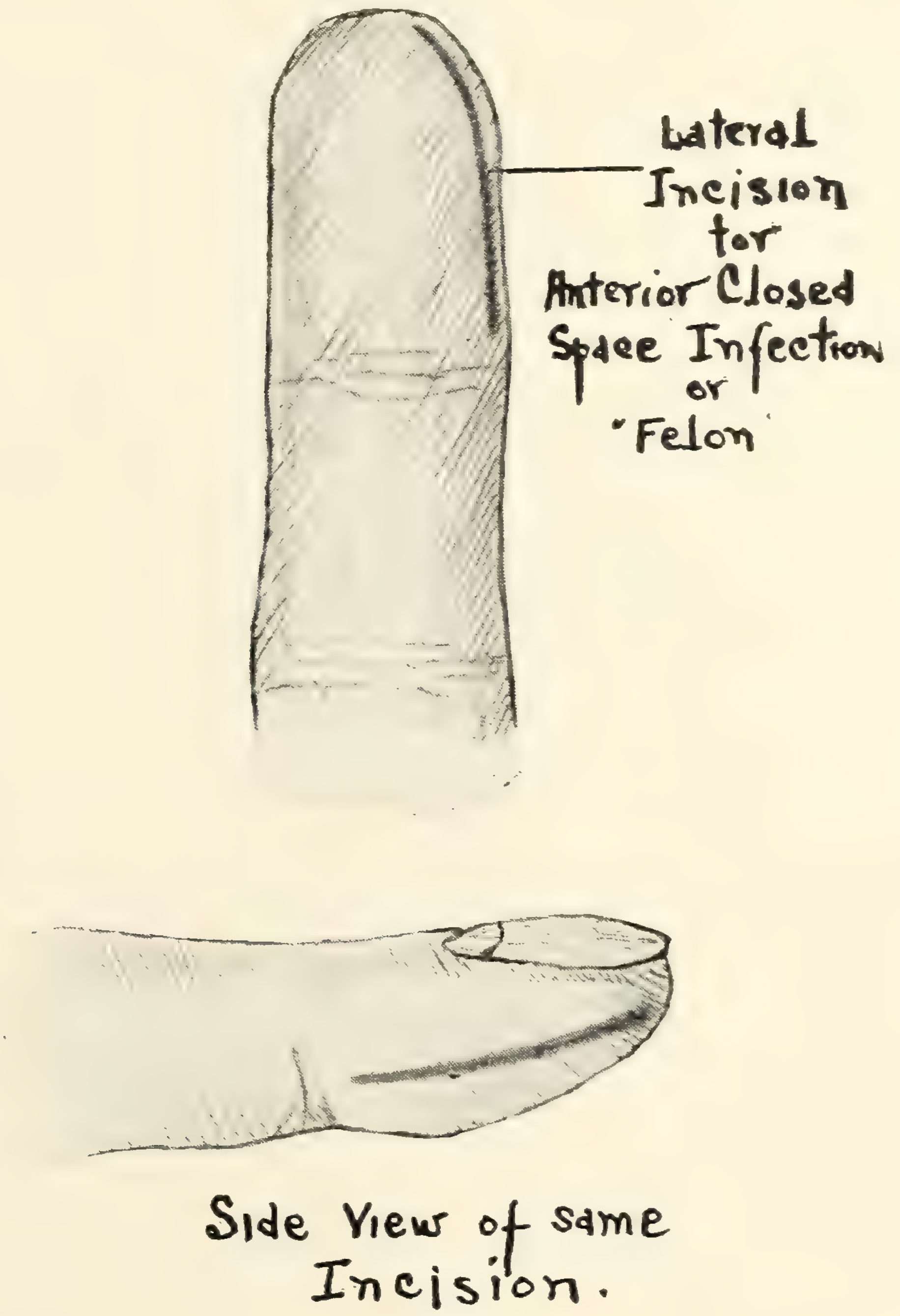

Figure 6. Drawing indicating the incision recommended for anterior closed space infection. It is located on the side, thereby avoiding the important tactile skin of the finger end. To effectively drain the various compartments in the anterior closed space, the connective tissue septa must be cut across. Extending this incision around the end of the finger is rarely necessary.

fat, large enough to over-distend the cavity thus created, is removed, through a small incision, from the abdominal wall and is inserted into the finger wound. The skin is then carefully sutured. I have used this operation a number of times and have been pleased with the final result.

Abscesses may develop over the front of either the middle or proximal phalanges. They are usually easily recognized and treated accordingly. In making incisions for infections, one should scrupulously avoid the flexion creases. At these points the flexor sheath is relatively unprotected and lies just beneath the skin. It may be opened very easily unless care is taken. Again, incisions should not cross flexion creases at right angles, because the resulting scar may produce a flexion contracture of the finger. If it becomes imperative to incise here, the wound should be made transversely in the crease.

Carbuncles. On the back of the hand abscesses may develop as elsewhere in the body. Only on the dorsum, however, are carbuncular infections found. The histology of the skin and subcutaneous tissues (already alluded to) here differs from that of the palm. As elsewhere, carbuncles are seen where there are hair follicles and, therefor, occur on the back of the hand proper and on the back of the proximal phalanges. The diagnosis is usually self-evident. The treatment should be radical and prompt. I believe that, in most instances, it is wiser to administer a general anæsthetic (gas-oxygen or ethylene) than to attempt local blocking with novocaine. Unless one can inject novocaine at a distance from an infected area, as in nerve blocking with finger-end infections, local anæsthesia in the treatment of infections, should be avoided. It has always seemed to me a most unsurgical procedure.

The incision used should be crucial and should extend to the outer limits of the area of induration. (Figure 12.) The four flaps thus produced must be undermined separately in order to adequately drain the infection. Gauze drains, moistened with hot saline, are inserted beneath the flaps and control the venous ooze. One should avoid cutting away what appears to be dead skin. On more than one occasion, I have been surprised to see the return of circulation in what appeared to be hopelessly dead tissue. Should skin sloughing really occur, skin grafting may be necessary to hasten healing.

While on the subject of lesions on the back of the hand, it seems apropos to emphasize the significance of the edema that occurs here with all severe infections. Because of the laxness of the tissues on the dorsum and the anatomical distribution of the lymphatics of the hand, all infections of any severity in the palm show the greatest swelling on the dorsum. Unless the palmar infection has been grossly mistreated or has been present for a long time, it is very unusual, indeed, to find pus on the dorsum. The appreciation of this clinical fact will prevent many ill-advised and unnecessary incisions on the back of the hand when the actual pathology is to be found in the palm.

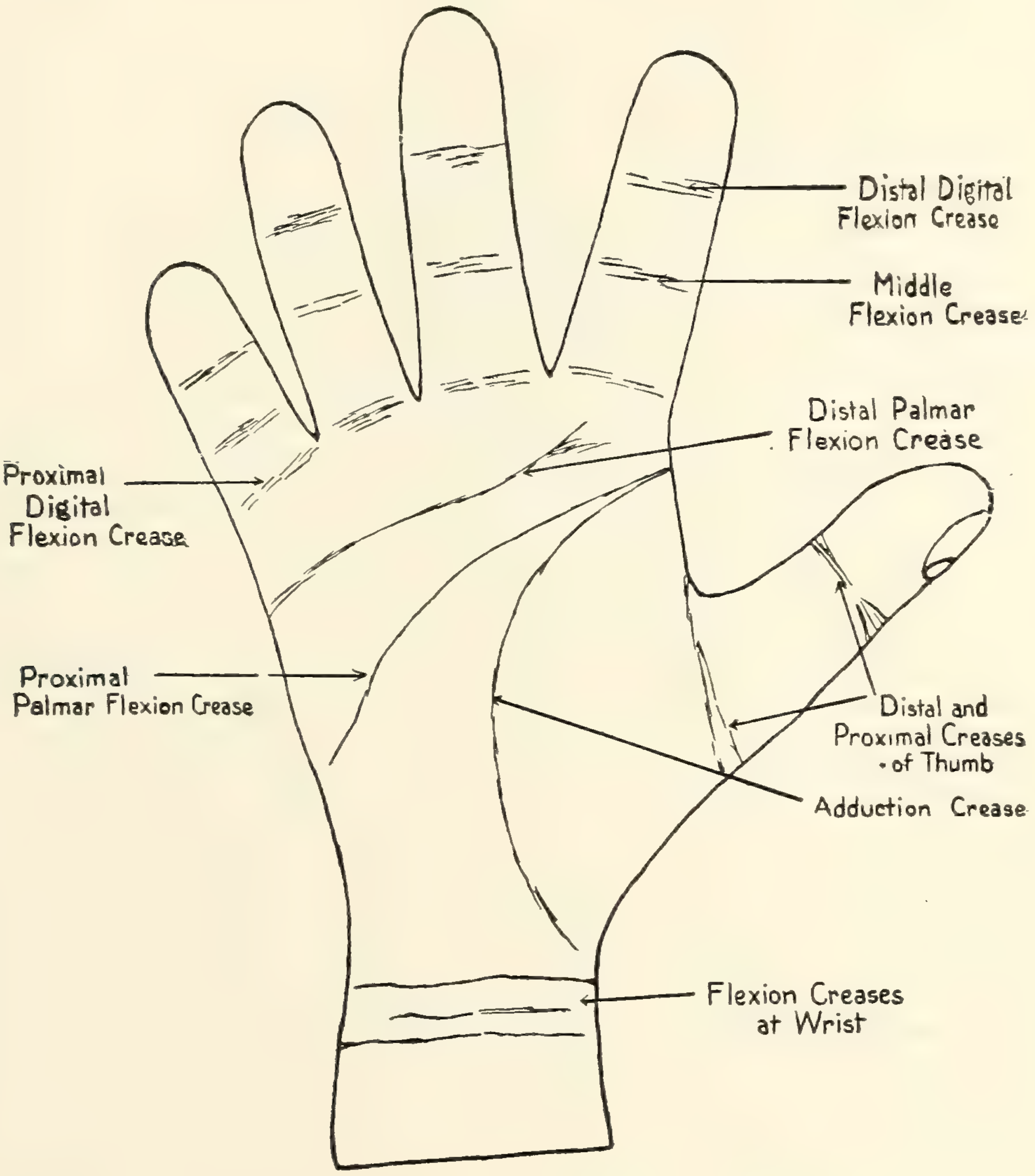
Distal Digital Flexion Crease
Middle Flexion Crease
Distal Palmar Flexion Crease
Proximal Digital Flexion Crease
Proximal Palmar Flexion Crease
Distal and Proximal Creases of Thumb
Adduction Crease
Flexion Creases at Wrist

FIGURE 7. Drawing of the palmar aspect of the hand to indicate the important skin markings. The digital flexion creases are of great importance because immediately beneath them lie the flexor tendon sheaths. The sheaths at these points are thinnest, the vaginal ligaments being located over the bodies of the phalanges. Injuries in the region of the digital creases are dangerous because of the possibility of the development of a tenosynovitis. The adduction crease marks the anatomical separation between the middle palmar and thenar spaces. The distal extremity of the middle palmar space is represented by a line connecting the inner end of the distal palmar crease and the outer end of the proximal palmar crease. The proximal palmar flexion crease represents the point near which the flexor tendon sheaths of the index middle, and ring fingers end. Incisions in the finger must never be made to cross flexion creases at right angles. Making such an incision greatly enhances the development of a flexion contracture.

Tendon sheath infections. Infections of the flexor tendon sheaths constitute the most important chapter in hand surgery. The virulence of the infections that may occur here, the speed with which tendon destruction takes place, the great possibility of a crippled hand, the not infrequent difficulty in diagnosis and the many complications that may develop, all and separately make the subject fraught with many difficulties. An understanding of the anatomical distribution of the sheaths is the prime requisite for intelligent management. (See Figure 8.) This has already been described in the section on anatomy. Secondly, one must have a clear conception of the possible modes of extension from a tenosynovitis of a given finger. In the author's experience, other factors have been found of great importance in the understanding of the subject:

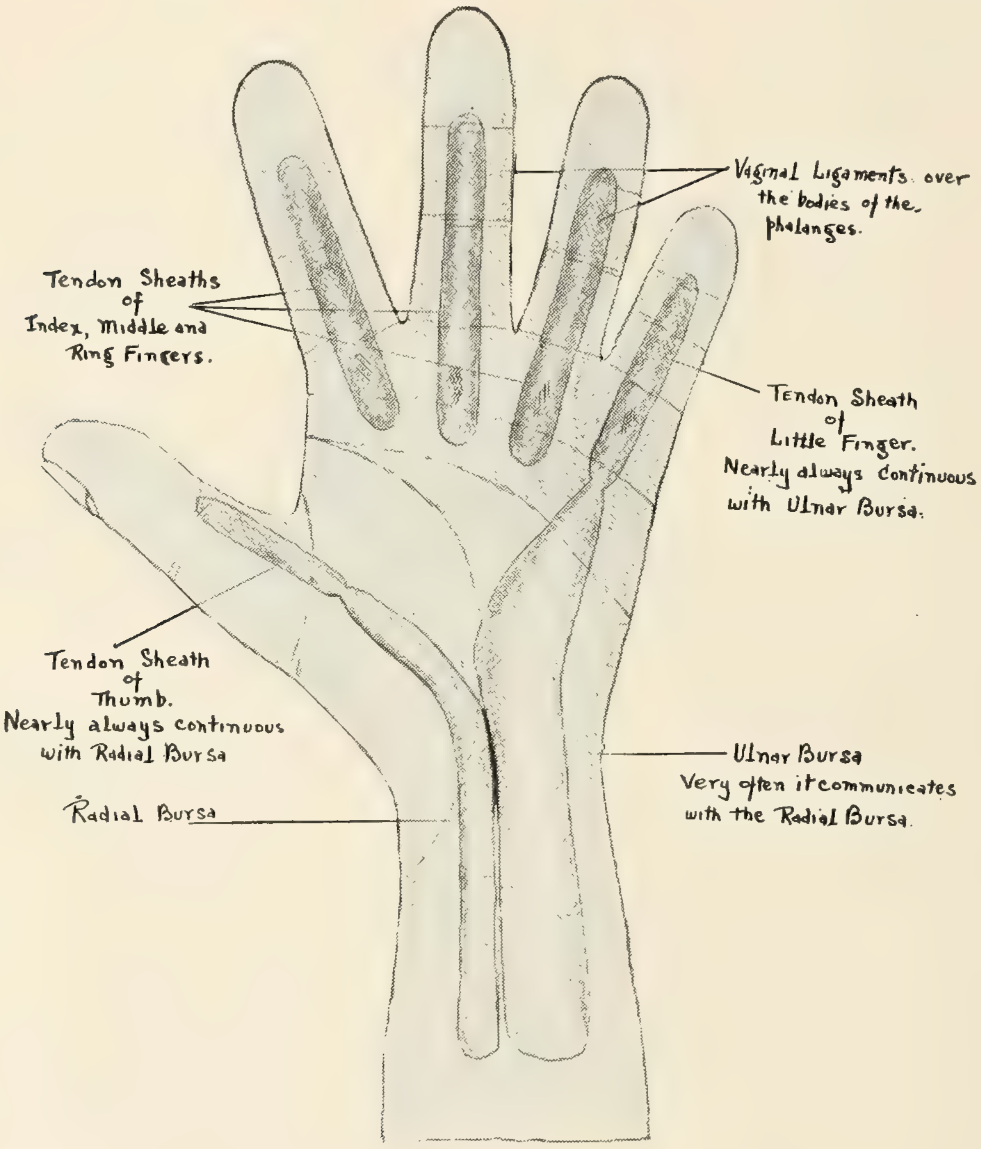
Vaginal Ligaments over the bodies of the phalanges.
Tendon Sheaths of Index, Middle and Ring Fingers.
Tendon Sheath of Little Finger. Nearly always Continuous with Ulnar Bursa.
Tendon Sheath of Thumb. Nearly always continuous with Radial Bursa
Radial Bursa
Ulnar Bursa Very often it communicates with the Radial Bursa.

FIGURE 8. Drawing to illustrate the position of the various flexor tendon sheaths and bursae projected to the surface of the hand. In the fingers it will be seen that the most vulnerable parts of the tendon sheath are situated beneath the flexion creases. For all intents and purposes the tendon sheath of the little finger must be considered continuous with the ulnar bursa. The same applies to the tendon sheath of the thumb and radial bursa. More often than not, the radial and ulnar bursa communicate with each other at about the level of the annular ligament.

I. The importance of a careful history. The accurate estimation of the time between onset of symptoms and examination by the physician.

VOL. I. 729.

II. The seriousness of wounds over the digital flexion creases and their frequent association with tendon sheath infections.

III. A very careful examination of the hand, with especial attention paid to skin coloration, distribution of swelling and edema, areas of tenderness and active and passive finger mobility. "Snap" diagnoses are bound to be wrong.

IV. Early radical operations.

V. The importance and necessity of careful intelligent postoperative care.

The cause of a tenosynovitis may be trivial indeed. Very often the patient does not remember any injury. In the vast majority of cases, direct inoculation at the point of injury is the causative mechanism, and most often the site is over one of the flexion creases. Tendon sheath infection may and does occur as an extension from some other hand infection. Occasionally, it may be hematogenous in origin, i. e., streptococcus hemolyticus or the gonococcus. In my experience, the most virulent infections have been caused by the hemolytic streptococcus.

The onset is usually sudden with severe throbbing pain in the involved part. Most often, the pain is most marked at the proximal end of the sheath in the palm. With the pain goes inability to move the finger. There is usually fever and prostration to a degree and there may be chills.

Upon examination, one finds that the involved finger is held in a rigidly semiflexed position. I have seen three or four patients with extensive infections who were able to flex and extend the involved parts rather freely. This, however, in my experience, is the exception. The entire digit is uniformly swollen and, on closer examination, it is noted that the sides of the adjacent fingers are also swollen. The dorsum of the hand is edematous. The color of the finger is a mottled red, its intensity being greatest on the sides and part of the dorsum, as well as the immediately adjacent hand. The outstanding and characteristically constant finding, is the exquisite tenderness localized directly over the course of the sheath and most marked at its proximal end. When an attempt is made to hyperextend the finger passively, pain is produced which is again of greater intensity at the proximal end of the sheath. This is another fairly constant physical sign. Occasionally, one may see a hand with the original wound draining pus and acting as a vent for the pus in the tendon sheath. In other words the sheath is open and tension is diminished. Diagnosis may be difficult at first, but it should be remembered that the physical signs enumerated above will still be present, although to a lesser degree.

When the tendon sheath of the little finger is infected, it should be assumed that the ulnar bursa is also involved because, in nearly every hand, the one is continuous with the other. Ulnar bursitis gives very definite physical signs. There is tenderness over the anatomical position of the bursa and often this tenderness is most marked at its proximal end above the wrist. The entire hand is swollen, especially on the dorsum. The other three fingers are held in flexion and become sensitive to pressure. Attempts at passive hyperextension are resisted because of pain. At the wrist, one finds swelling and a violaceous skin coloration. The wrist flexion creases become more conspicuous. Another important finding is rigidity of the thumb and tenderness over the radial bursa and the flexor tendon sheath. Only at operation, by pressing over these structures, can one be sure whether or not infection in these sheaths exists also. In late cases, it is certain that the radial bursa and the thumb flexor sheath will be found involved. In early cases, it is problematical.

As in the little finger, when the tendon sheath of the thumb is infected, it should be assumed that the radial bursa is also involved because the former is nearly always continuous with the latter. The physical signs are quite distinctive and, when looked for, the diagnosis should rarely be difficult. It will be seen that the thumb is held rigidly in semi-flexion and that the entire thenar eminence is quite swollen. The redness of the skin is mottled and distributed over the entire thumb, thenar eminence, and anterior aspect of the wrist where it assumes a violaceous tinge. The edema on the dorsum of the hand is quite pronounced. The entire thenar eminence is tender and in most instances the tenderness is more pronounced at the upper end of the radial bursa above the wrist. It may be noted that the hand is held in moderate flexion and radial deviation. With infection of the radial bursa alone, and this is seen only in early cases, an important negative finding is the absence of pain and the relative freedom of motion in the other fingers. The sudden development of pain in these fingers and the assumption of a position of rigid semi-flexion with resistance to extension, coupled with a progression of the area of tenderness, both in the hand and above the wrist, means only one thing, a secondary involvement of the ulnar bursa. In my experience, however, it has been found that in the majority of instances both the radial and ulnar bursæ are already involved when the patient presents himself for treatment. It is only in the early cases where one may be able to diagnosticate involvement of only one or the other structure. This frequent simultaneous infection is due to the fact that in the majority of instances the radial and ulnar bursæ communicate with one another anatomically.

As soon as the diagnosis of tendon sheath infection is made, operation should be prompt. In fact, *every hand infection should be considered a surgical emergency.* Great importance attaches to the time of operation in its relationship to the time of onset of symptoms. I have found in a series of cases that the time element bears a definite relationship to the prognosis. Cases that were operated upon within twelve hours of the onset of symptoms gave the best end-results. Those coming for treatment between twelve and twenty-four hours after the onset of symptoms also gave the greatest number of good end-results. After this period of time, the number of recoveries with function diminished proportionately to the duration of the illness. In other words, the longer the period of time between the onset of symptoms and the operation, the more chance there is for sloughing of tendons and the less likelihood for a satisfactory end-result. The patient should be put to bed and kept there following operation until the temperature has been normal for four or five days.

A general anæsthetic should be administered. During the past few years, I have used ethylene almost exclusively. No one should ever attempt to operate for a suppurative tenosynovitis with local anæthesia.

The operation is best performed in a bloodless field. This can be obtained by a properly applied Esmarch bandage beginning at the fingers and ending at the upper third of the forearm. If the operation consumes less than an hour, the Esmarch bandage may be left in place and gradually loosened during the hour following the operation. This tends to prevent the rapid absorption of toxins from the site of operation. No harm has ever resulted, in my experience, from the use of an Esmarch in this way. A good light is a prime requisite. Instruments should be small and very sharp. The operation should be performed with as little trauma to the tissues as possible. In the finger proper, the incision is made on the side as indicated in the accompanying diagrams. (Figure 9.) Great care should be exerted to prevent any operative injury to the digital nerves. By careful dissection, the subcutaneous tissues are dissected away from the front of the tendon sheath as far as the side opposite to the incision. The incison in the tendon sheath is made over its anterior aspect, and should be segmented. This is advisable to prevent prolapse of the tendons. A small part of the tendon sheath over the interphalangeal joints should be left intact. In the palm, the skin incision should be made slightly to one side of the anatomical position of the tendon sheath so as to prevent, in healing, the agglutination of the skin scar to the tendon sheath. The palmar prolongation of the tendon sheath is opened throughout its whole extent. In infections of the ulnar bursa, the skin incision should be extended as far as the anterior annular ligament, more toward the ulnar side of the hand. Should the tendons in the neighborhood of the wrist show marked swelling, and should the infection be a virulent one, one need have no hesitancy whatsoever in completely dividing the anterior annular ligament along the line of incision. The writer finds that he is following this procedure more and more as his experience with hand infections becomes more extended. With the hand splinted for a few days in hyperextension, prolapse of the tendons does not occur. No untoward later effects were noted which could be attributed to the cutting of this ligament. The incision in the ulnar bursa proper should be a long one, and placed over its ulnar side. To drain the prolongation of the bursa above the wrist, the best approach has been found to be through a side incision. The dissection at this point should be very careful and painstaking to prevent injury to the ulnar artery. It is to be remembered that the bursa lies to the ulnar and posterior sides of the flexor tendons. These must be identified and gently retracted externally. The bursa should be opened throughout its extent in this situation.

In infections of the flexor tendon sheath of the thumb, one ought always to assume that an extension has already occurred into the radial bursa because in most instances the tendon sheath is continuous with the bursa. The incision for this infection, therefor, starts along the inner side of the proximal phalanx of the thumb, and curves slightly outward into the thenar eminence. By careful dissection, the two heads of the flexor brevis pollicis muscle are identified and separated and access is gained to the palmar portion of the bursa. In making the dissection, it is better to separate muscle bundles in the direction of their fibres than to divide them. Attention is called here to the fact that the skin incision should end about one inch distal to the anterior annular ligamant, in order to prevent injury to a small nerve, a branch of the median which supplies the abductor, opponens, and superficial head of the flexor brevis pollicis muscles. (See Figures 9 and 33.) Injury to this nerve results in a crippling disability and its importance to hand function can never be overemphasized. The upper end of the radial bursa above the annular ligament is best approached through a lateral radial incision just above the wrist. Here particular care must be taken to avoid injury to the radial artery. At times, it may be advisable to retract this structure mesially. At other times, it may be more feasible to leave the radial artery alone and approach the radial bursa from in front of it. Again it is to be remembered that the flexor longus pollicis tendon lies deeply and, therefor, the bursa is deeply placed. When reached, it should be incised throughout its length in this situation. Attention is called to the fact that these side incisions, when of adequate length, very effectively drain the upper prolongations of both the radial and ulnar bursæ.

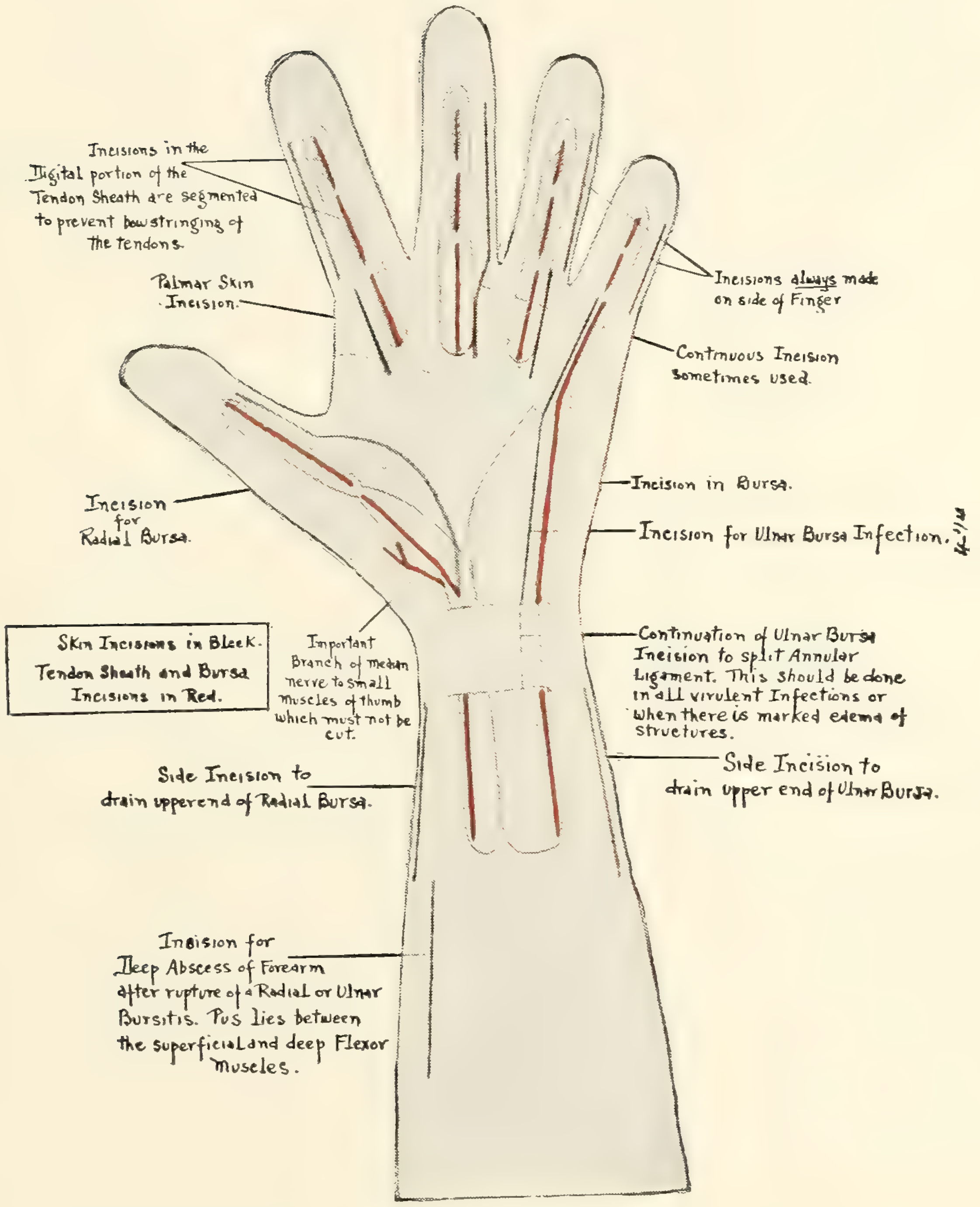
Incisions in the Digital portion of the Tendon Sheath are segmented to prevent bowstringing of the tendons.
Palmar Skin Incision.
Incision for Radial Bursa.
Skin Incisions in Black. Tendon Sheath and Bursa Incisions in Red.
Important Branch of median nerve to small muscles of thumb which must not be cut.
Side Incision to drain upper end of Radial Bursa.
Incision for Deep Abscess of Forearm after rupture of a Radial or Ulnar Bursitis. Pus lies between the superficial and deep Flexor muscles.
Incisions always made on side of Finger
Continuous Incision sometimes used.
Incision in Bursa.
Incision for Ulnar Bursa Infection.
Continuation of Ulnar Bursa Incision to split Annular Ligament. This should be done in all virulent Infections or when there is marked edema of structures.
Side Incision to drain upper end of Ulnar Bursa.

FIGURE 9. Drawing illustrating incisions recommended for infection of the flexor tendon sheaths and ulnar and radial bursæ. In the fingers, the skin incisions are always made laterally. The incisions in the sheath itself should be segmented to prevent bow-stringing of the tendons. The continuous incision indicated in the middle finger is sometimes used for virulent infections with great swelling of the tissues. The incision for radial bursitis is important and should end about an inch distal to the distal edge of the anterior annular ligament so as to prevent injury to the thenar motor branch of the median nerve. In ulnar bursa infections, thorough drainage may be obtained by splitting of the anterior annular ligament. This should be to one side rather than through the middle of this structure. The upper prolongations of the radial and ulnar bursæ above the wrist are best drained through side incisions, the bursae being approached behind the flexor tendons. The incision for deep abscess of the forearm subsequent to the rupture of a radial or ulnar bursitis, is made more anterior than the incisions used for the bursa infections above the wrist.

After the infected sheath has been opened as described, the question arises as to what type of drainage material should be used. In general, it can be said that the number of cases with postoperative tendon sloughing and poor functional results is almost directly proportional to the type of drain used and the duration of its employment. Therefor, it seems wiser to insert the most innocuous type of drainage material and to cut its time of employment to a minimum. Drains should never be inserted into a tendon sheath because the slightest trauma to this structure is to be avoided. If the wound in the skin and subcutaneous tissues is kept open, adequate drainage will ensue. A small strip of silk tape or fine gutta-percha may be inserted *down to, but not into* the tendon sheath. The skin wound may be kept patent by a strip of gauze lightly impregnated with vaseline. The postoperative course of the infection will guide the surgeon in determining how long drainage should be continued. The vaseline gauze should be removed in twenty-four hours and the other drains usually within forty-eight hours.

Some years ago, the writer found that the incidence of postoperative sloughing of tendons dropped markedly when every effort was made to prevent contamination and secondary infection by organisms other than that cultured from the tendon sheath at operation. When secondary infection occurred, the probability of tendon necrosis was greatly enhanced. This finding emphasized the great importance of performing all postoperative dressings and treatments under the most rigid aseptic precautions. I believe that every effort should be made in all infections to adhere to this rule, but especially so in suppurative tenosynovitis. To prevent, therefor, such secondary infection, the surgeon should consider the extremity from finger tips to above the elbow sterile, and treat the entire region as a clean operative field. After the operation is completed, and the dressings are applied, the arm is wrapped in sterile towels and placed in a specially constructed muslin bag which closes above the elbow with a string. During the first twenty-four hours, the hand and forearm, after careful removal of the bag and towels, are placed in a sterile arm bath of hot saline or boric acid solution every four hours. The extremity is kept in the hot solution for a period of fifteen to twenty minutes. Following each soak, the arm is again wrapped in sterile towels. During the second twenty-four hours, instead of the hot soaks, warm solution may be poured upon the dressings every three or four hours and the sterile towels reapplied. It seems inadvisable to prolong this treatment more than forty-eight hours because of the possibility of water-logging the tissues. After forty-eight hours, the hand may be placed beneath a therapeutic lamp two or three times a day for five or ten minutes at each sitting. This tends to induce hyperemia and dry up the wounds. It is doubtful whether dressings should be done oftener than once a day because of the possibility of contamination. At each dressing, secretion is gently wiped away with wisps of moistened cotton and the patient is encouraged to actively flex and extend the involved digits. This active motion should be *within the limits of pain.* Gentle passive motion is permissible. Any forcible passive motion is decidedly contra-indicated. The patient will find that when the hand is immersed in hot solution, he is able to move the involved fingers to a greater extent. This also occurs when the hand is placed beneath a therapeutic lamp. When the operative wounds have healed to a point where they are superficial granulating areas, gentle massage of the entire hand may be instituted. After the operative wounds have healed completely, baking and massage treatment should be given. Constant active motion within the limits of pain should be the watchword in the postoperative treatment of these infections. Every effort is to be made to prevent a flexion contracture of the finger. The optimum result following a suppurative tenosynovitis may not be evident until the expiration of three to six months. (See Figures 14, 15, 16, 17, 18, and 21.)

Not unfrequently in a radial or ulnar bursitis, rupture of the upper extremity of the bursa occurs and pus accumulates in the deep recesses of the forearm upon the pronator quadratus muscle. In making the side incisions recommended for radial or ulnar bursitis the surgeon can determine whether such rupture has already taken place. By gentle pressure over various portions of the forearm the distribution of the pus may be determined. As pointed out in the section on anatomy, pus accumulates between the superficial and deep flexors. Therefor, if extension up the forearm has already occurred, an additional side incision is indicated. This is made on the radial side slightly more anterior to the incision used to drain the radial bursa. Pus will be found lying between the flexor profundus and flexor sublimis digitorum muscles. If the exudate follows the course of the ulnar artery, it may proceed distally under the flexor carpi ulnaris and come to lie subcutaneously two or three inches above the wrist on the ulnar side. Rarely, the pus may follow the course of the median nerve and reach the cubital fossa. The latter two extensions are found only in late cases.

Abscess of the middle palmar space. Infections of this clearly defined fascial compartment are frequently overlooked or incorrectly diagnosed. There are many reasons for this. In the first place, the space is so deeply situated that, coupled with the super-imposed relatively nonresistant palmar fascia, the physical signs are not as distinctive as in infections of tendon sheaths or the thenar space. Then again, the signs and symptoms of the preexisting or simultaneous infection of one of the tendon sheaths or the presence of some crushing injury to the hand may overshadow the mid-palmar infection. It must be remembered as pointed out before that this space is situated deeply in the hand behind the flexor tendons and lumbrical muscles and in front of the metacarpal bones and the interosseous muscles with their overlying fascia. (See Figure 10.)

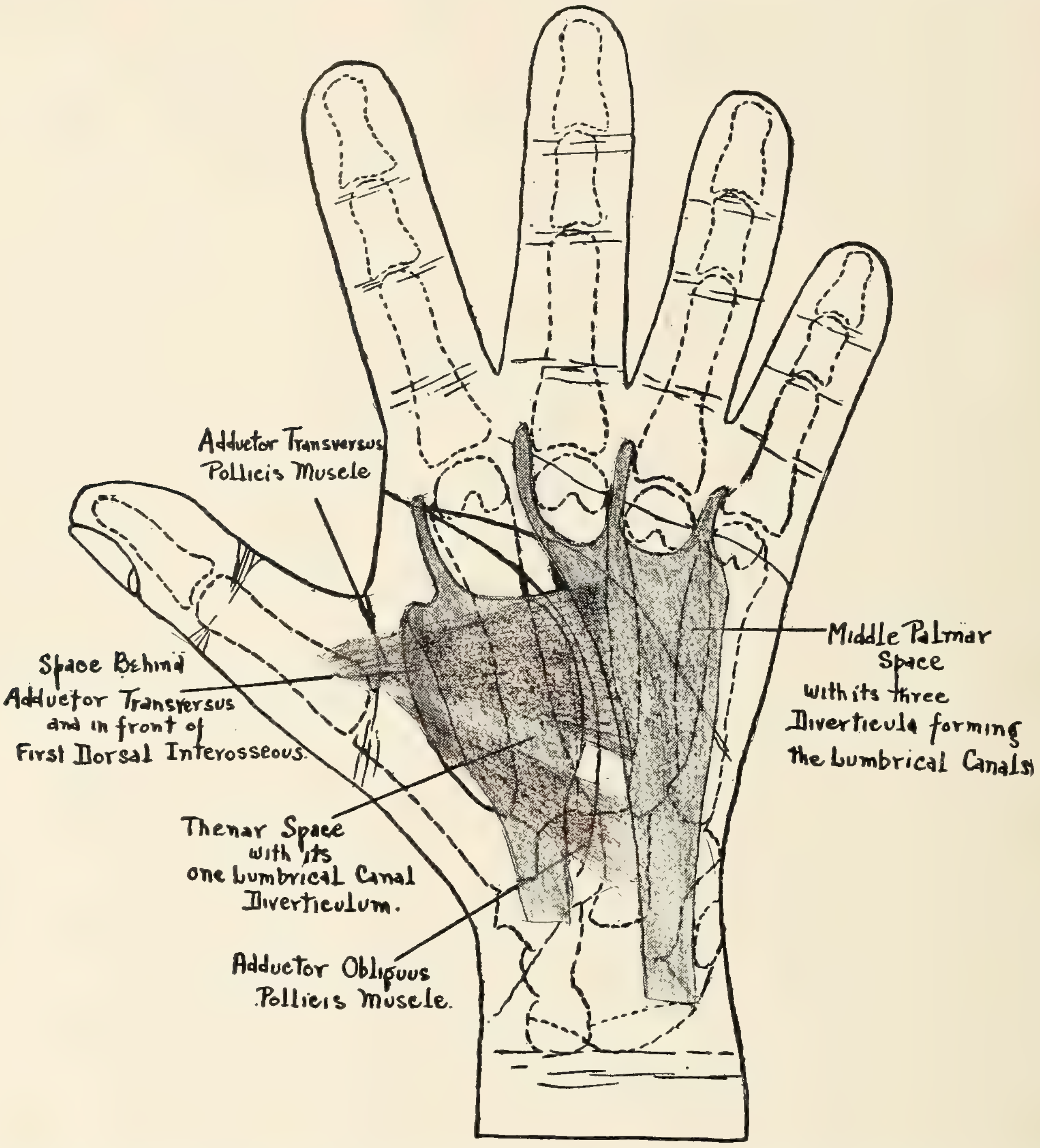
Adductor Transversus Pollicis Muscle
Space Behind Adductor Transversus and in front of First Dorsal Interosseous.
Thenar Space with its one Lumbrical Canal Diverticulum.
Adductor Obliquus Pollicis Muscle.
Middle Palmar Space with its three Diverticula forming the Lumbrical Canals

FIGURE 10. Drawing illustrating the anatomical position of the middle palmar and thenar spaces projected to the surface of the hand. The origin of the adductor transversus pollicis muscle from the third metacarpal is the key to the anatomical detail here. The middle palmar space lies behind the flexor tendons and anterior to the metacarpal bones and the anterior interosseous fascia. It gives off three diverticula, the lumbrical canals. The thenar space lies anterior to the adductor transversus muscle, being separated from the middle palmar space by a fascial septum. It gives off a diverticulum, the lumbrical canal of the index finger. Pus may extend behind the adductor transversus and come to lie between it and the first dorsal interosseous muscle. The relation of these spaces to the skin markings should be noted.

The main subjective complaints are severe pain confined to the palm and a rapid increase in size of the hand. Objectively one finds that the entire hand is enormously enlarged, especially on the dorsum. The palm, the web spaces between the middle, ring and little fingers, and the adjacent dorsum present a livid color. The outstanding positive objective finding is the loss of the concavity of the palm which now appears to bulge. This is best seen by viewing the hand from the side. Because of the anatomical proximity of the tendon sheaths of the middle, ring and

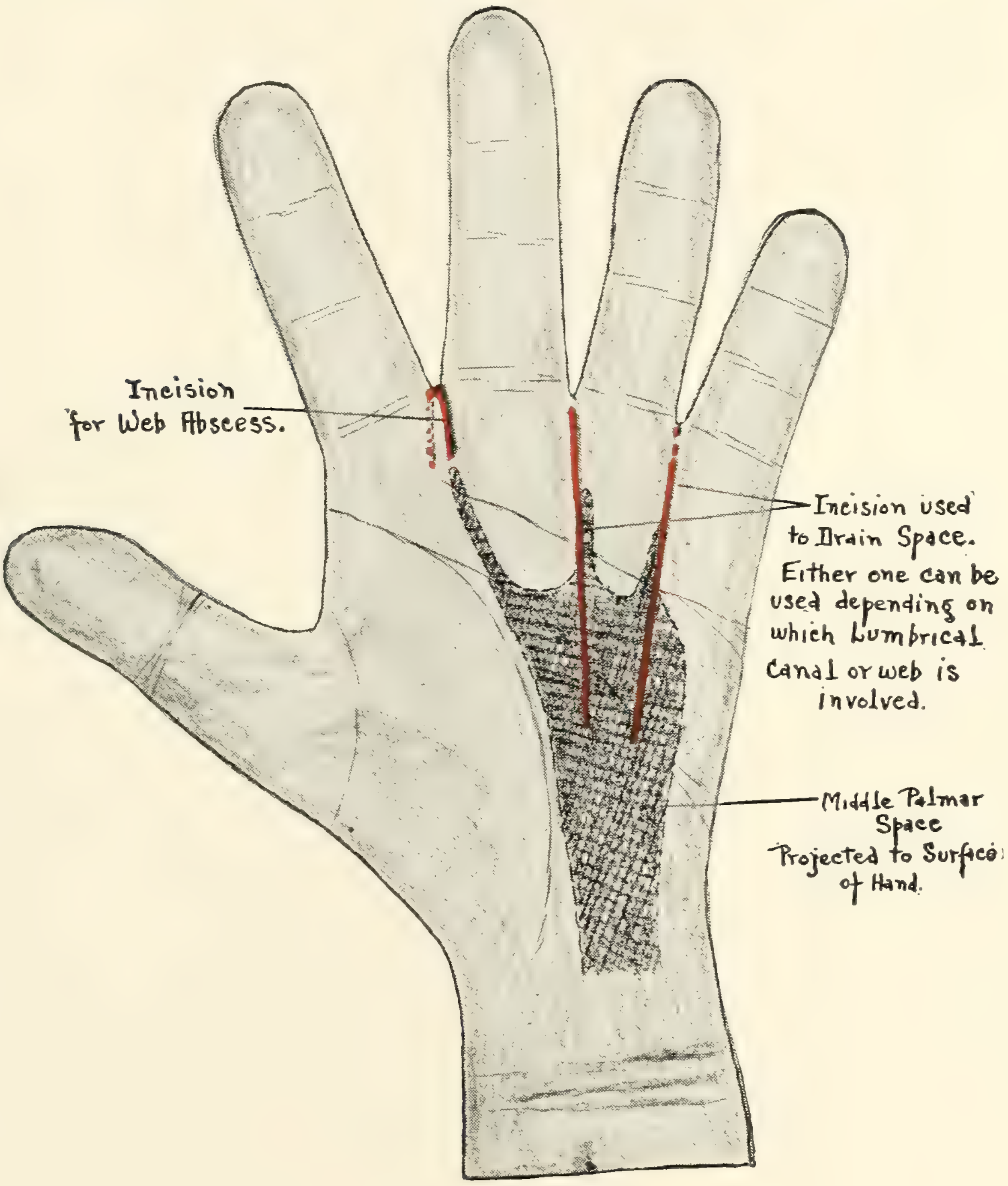
Incision for Web Abscess.
Incision used to Drain Space. Either one can be used depending on which Lumbrical Canal or web is involved.
Middle Palmar Space Projected to Surface of Hand.

FIGURE 11. Drawing illustrating the position of the middle palmar space projected to the surface of the hand and the incisions used to drain infections of this space. The incisions may be extended distally to drain an associated lumbrical canal or web infection. Great care must be exerted to prevent injury to the digital nerves. A clamp inserted behind the flexor tendons enters the space. The illustration also indicates the incision used for isolated web space infections. The web may be split from before backwards without fear of subsequent deformity or impairment of function.

little fingers, these digits assume a semi-flexed position. The thenar eminence, because of the laxity of its tissues, is swollen, but this swelling is of the soft edematous variety as differentiated from the firm induration seen in thenar space infection. There is induration in the palm and tenderness most marked over the anatomical position of the space. Very often, because of the associated tendon sheath infection, diagnosis may be difficult. I believe, however, that the condition can usually be determined before operation if the signs and symptoms are sought for carefully and intelligently.

The most important phase of the treatment is a properly placed radical incision. This is indicated in the accompanying picture. (See Figure 11.) One or the other incision can be made, and the associated lumbrical canal infection, if present, may be drained at the same time. The flexor tendon sheaths are pushed aside and an artery clamp is inserted behind them into the space. Separation of the blades produces a satisfactory drainage opening. A strip of rubber dam is inserted into the furthest extremity of the space. The postoperative treatment is the same as in tendon sheath infection. Following a properly placed incision, one is impressed with the rapidity of recovery in these cases. It is important to institute early massage to prevent adhesions about the superimposed flexor tendon sheaths.

Abscess of the thenar space. This clearly defined fascial compartment may be infected by direct inoculation, as a result of a compound fracture of the index metacarpal bone or following an extension from a tenosynovitis of the index finger or thumb or radial bursa. As stressed in the section on anatomy, this space is situated deeply in the thenar eminence to the radial side of the middle palmar space from which it is separated by a fascial septum, and lying *upon* the anterior surface of the adductor transversus pollicis muscle. (See Figure 10.) Pus may pass between the latter structure and the adductor obliquus pollicis and come to lie in front of the first dorsal interosseous muscle from which situation it passes quickly to the web region between the thumb and index finger. The physical signs are quite distinctive. The entire hand is swollen. The thenar eminence stands out markedly, giving the appearance of capacity distention. The thumb appears to stand away from the rest of the hand with the terminal phalanx held in acute flexion. There is marked edema on the dorsum. Motion in the thumb and index fingers is restricted. The thenar eminence, the first web space and the adjacent back of the hand and thumb display a mottled cyanotic coloration. There is marked tenderness over the thenar eminence and usually the web between the thumb and index finger. A constant positive physical sign is the induration of the whole thenar eminence.

The essential factor in treatment consists in a properly placed incision. As indicated in the diagrams. (See Figure 12) the most satisfactory approach to the thenar space is through an incision on the dorsum of the first web region parallel to the index metacarpal bone. This incision avoids injury to the intrinsic muscles of the thumb. By careful dissection the edge of the first dorsal interosseous muscle is identified and an artery clamp is inserted anterior to the adductor transversus pollicis muscle.

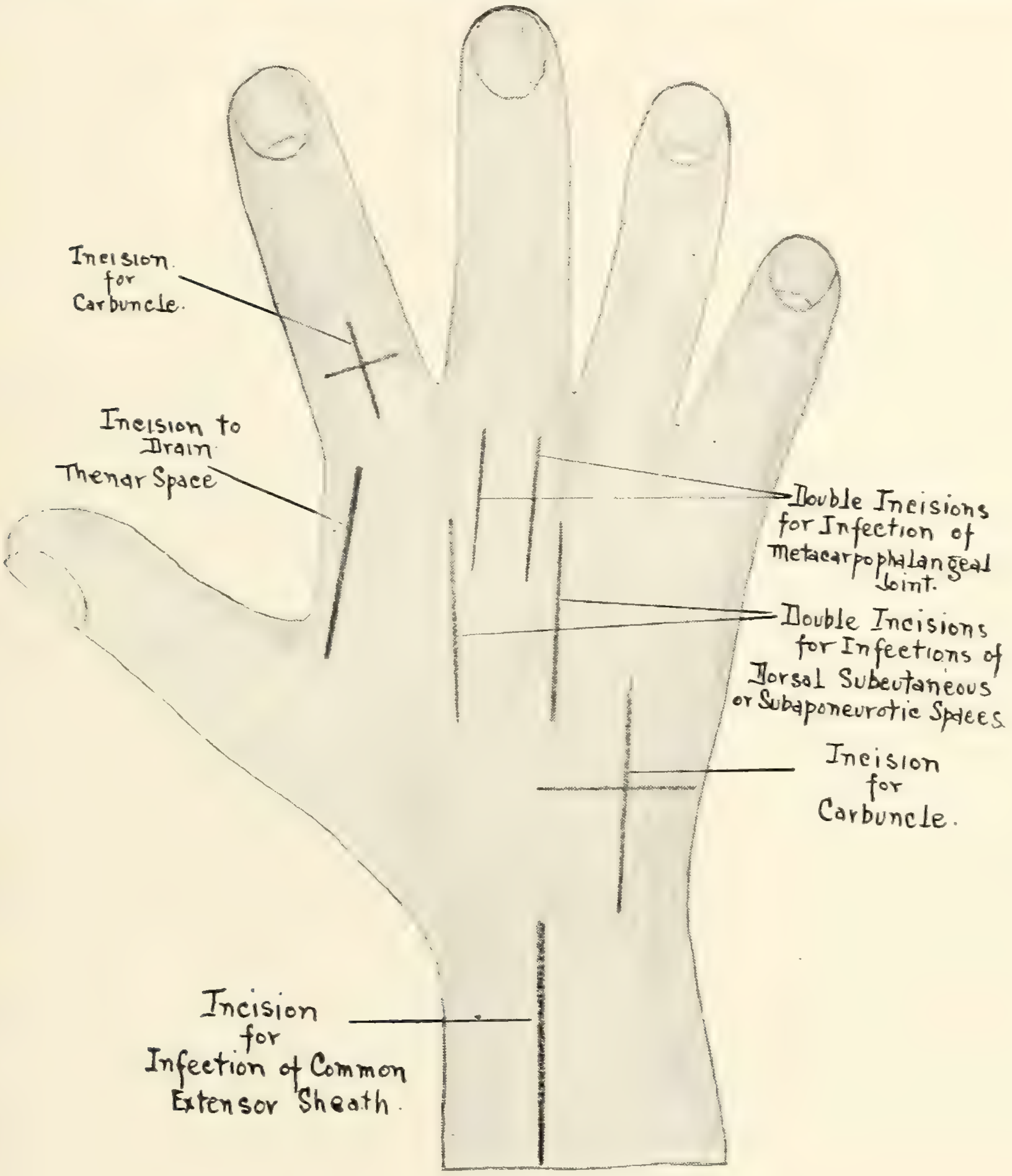
Incision for Carbuncle.
Incision to Drain Thenar Space
Double Incisions for Infection of Metacarpophalangeal Joint.
Double Incisions for Infections of Dorsal Subcutaneous or Subaponeurotic Spaces
Incision for Carbuncle.
Incision for Infection of Common Extensor Sheath.

FIGURE 12. Drawing of the back of the hand with incisions used for various infections that may occur in this region. The incision to drain the thenar space runs somewhat parallel to the metacarpal bone of the index finger. A clamp is inserted anterior to the adductor transversus pollicis muscle. It must never be pushed through the fascial septum which separates the thenar and middle palmar spaces. A crucial incision with thorough undermining of the four flaps is used for carbuncular infections. Infections of the dorsal subcutaneous and subaponeurotic spaces may be drained by multiple incisions placed to one side of the extensor tendons. Infections of the common extensor tendon sheaths are drained by an incision which involves splitting of the posterior annular ligament.

Care should be taken not to push the clamp through the fascial septum separating the thenar from the mid-palmar spaces. Pus may also be found behind the adductor muscle of the thumb. A drain in the form of a strip of rubber dam is placed down to the bottom of the space. The postoperative treatment carries out the same details as already described in the section on tenosynovitis.

Infections of the extensor tendon sheaths. Rarely, the sheaths of the extensor tendons may become involved in an infection. As has already been pointed out, there are no tendon sheaths on the dorsum of the fingers. The tendons of the extensor communis digitorum have a common sheath in the region of the posterior annular ligament. In addition to this tendon sheath, the following tendons have individual sheaths: extensor carpi radialis longior and brevior, extensor longus pollicis, extensor ossis metacarpi pollicis, extensor indicis, extensor minimi digiti, and the extensor carpi ulnaris.

I have seen three cases of infection of the common sheath of the extensor communis digitorum tendons. In each instance, the causative mechanism was a wound on the back of the wrist with direct implantation of organisms into the sheath. Subjectively, each patient complained of severe pain over the dorsum of the hand, with pain on flexion of the fingers. On clinical examination, the outstanding signs were edema and redness over the dorsum of the hand, wrist, and lower forearm, exquisite tenderness over the back of the wrist, carpus and hand, slight dorsiflexion at the wrist joint, and slight flexion of the finger joints. In each of the three cases observed, pressure over the tender area caused pus to appear at the original wound.

It can be seen that the differential diagnosis of this infection offers difficulties. It might easily be confused with an infection of either the dorsal subaponeurotic or the dorsal subcutaneous spaces. From the experience gained in the three cases observed, it would seem that a longitudinal incision (See Figure 12) to one side of the anatomical position of the tendon sheath with complete opening of the sheath itself, which would also include splitting of the posterior annular ligament, constitute the main factors in the surgical treatment. The postoperative treatment follows the same course as indicated in our consideration of infections of the flexor tendon sheaths.

Phlegmonous lymphangitis. Many of the hand infections that one sees are accompanied by a lymphangitis of varying degree of the hand and forearm and often of the arm and lymph-adenitis of either the epitrochlear or axillary glands or both. These cases of simple lymphangitis and lymphadenitis, characterized clinically by red streaks along the course of the lymph vessels and enlarged tender regional lymph nodes, generally subside after drainage of the focus in the hand and application of hot wet dressings to the part exhibiting the lymph vessel or node involvement. Occasionally, however, these secondary lymph infections break down and suppurate, thus requiring incision. This most commonly occurs in the axilla, and next most frequently at the inner side of the elbow.

There is, however, another form of lymphangitis which Kanavel has characterized as a phlegmonous infection. It is manifested by severe local, and often general, manifestations in which there is an appreciable mortality rate. Recently, Meleney described a condition, called by him Hemolytic Streptococcus Gangrene, which fits in accurately with the disease as I have seen it. The point of origin may be an insignificant wound, usually on the dorsum of one of the fingers or the hand. With this as a focus, the infection spreads rapidly and appears to be confined to

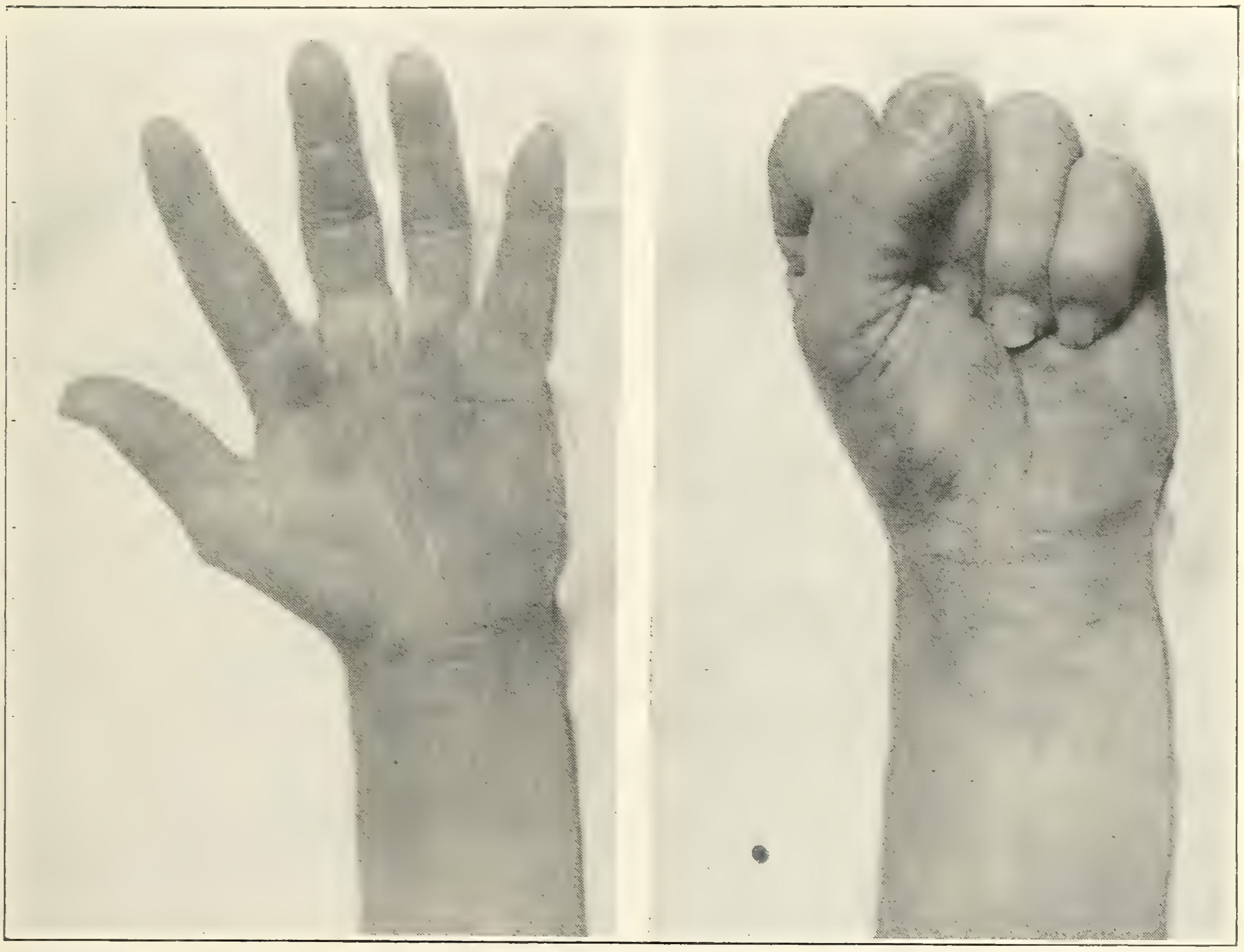

FIGURE 13 (*a* and *b*). Double web space infection due to a collar button abscess at the distal edge of the palm over the middle finger metacarpal bone. The photographs indicate the incisions which split the web from before backwards. The function at the end of the 4th postoperative day is noteworthy.

the lymphatics of the skin and subcutaneous tissues on the dorsum of the hand, of the forearm and very often of the arm. Instead of the relatively soft, pink, pitting edema which accompanies the simple lymphangitis, the great swelling which follows the onset of this infection is indurated and bluish in color. The skin soon becomes covered with small vesicles and presents an appearance suggestive of erysipelas. The patient complains of severe throbbing pain in the involved parts, and presents clinical evidence of an intoxication of varying severity, with high temperature, rigors, prostration, etc. Locally, one finds none of the symptoms and signs of tendon sheath or fascial space infection. Whether the symptoms of this lymphangitis overshadow possible infections in these regions, or secondary infection occurs at a later period, it has been noted that these spaces often do show evidences of involvement at some later stage of the disease. The characteristic finding is the bluish, firm, indurated swelling of the superficial tissues on the back of the hand, forearm, sometimes extending to the shoulder. In the presence of such an infection, incision is indicated, for it

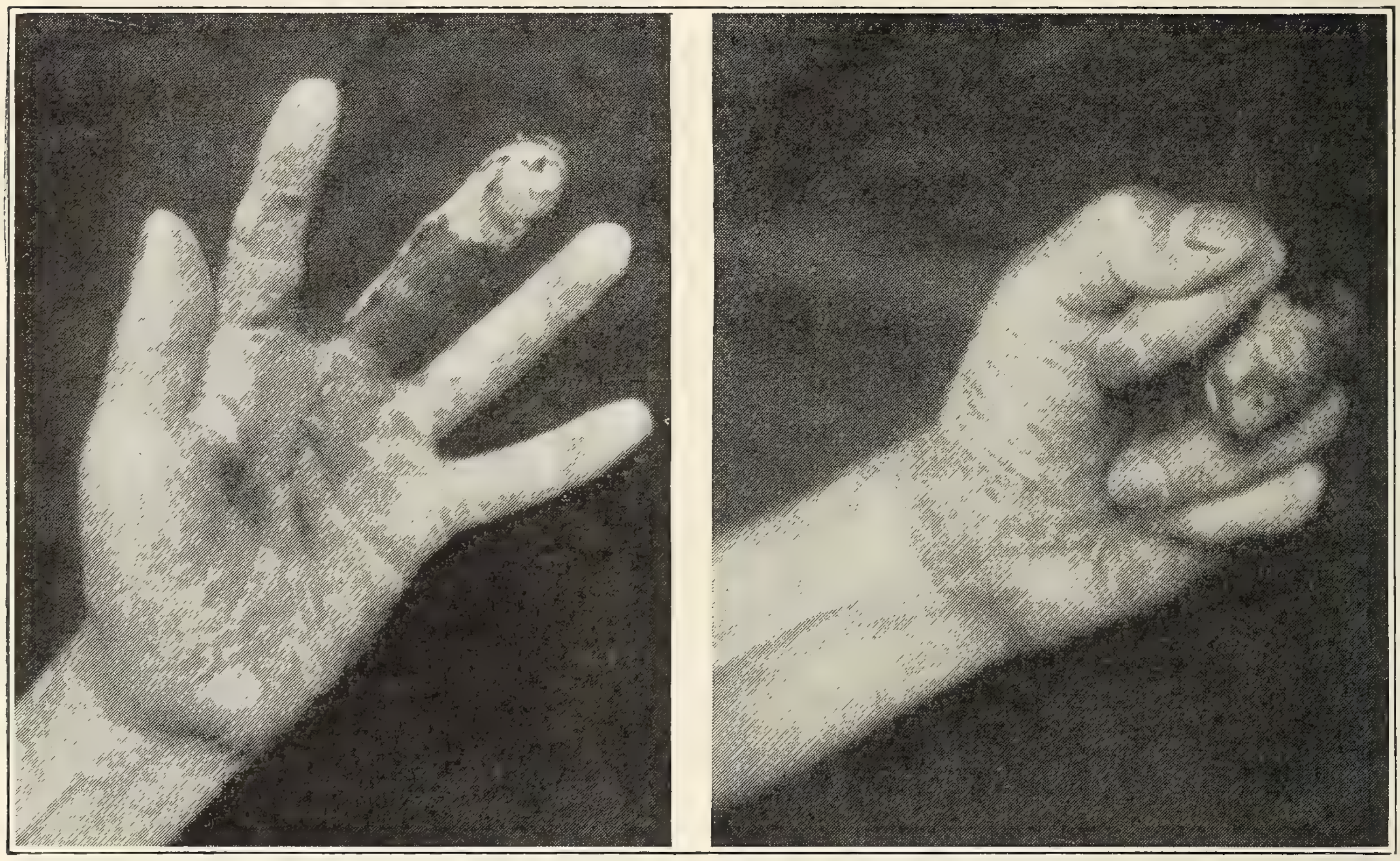

FIGURE 14 (*a* and *b*). Suppurative tenosynovitis of the flexor tendon sheath of the middle finger complicated by a felon with necrosis of the tuft of the distal phalanx. This patient was operated upon approximately 24 hours after the onset of symptoms. The small amount of blood tinged fluid revealed staphylococcus hemolyticus. A smear showed many leucocytes, but few organisms. The photographs indicate the lateral digital incision, the separate palmar incision placed to one side of the anatomical position of the flexor tendons, and the incision for drainage of the anterior closed space infection. The degree of active flexion on the 6th post-operative day is noteworthy. The eventual outcome was a return of complete function.

is found that the skin is completely undermined by pus and the subcutaneous tissues and superficial fascia are grossly necrotic and can be removed in large pieces. In some cases the entire superficial fascia and most of the subcutaneous tissue of the forearm and the back of the hand become necrotic. In the event of such extensive involvement, the vitality of the overlying skin becomes impaired and soon isolated areas of skin gangrene are visible and they coalesce or individually increase in size until extensive parts of the hand and forearm become denuded of skin, necessitating prolonged convalescence and secondary skin grafting. In some cases, the infection may be so severe as to overwhelm the patient. It is in this type of infection, as in some of the virulent tendon sheath infections that the prognosis as to life should be guarded.

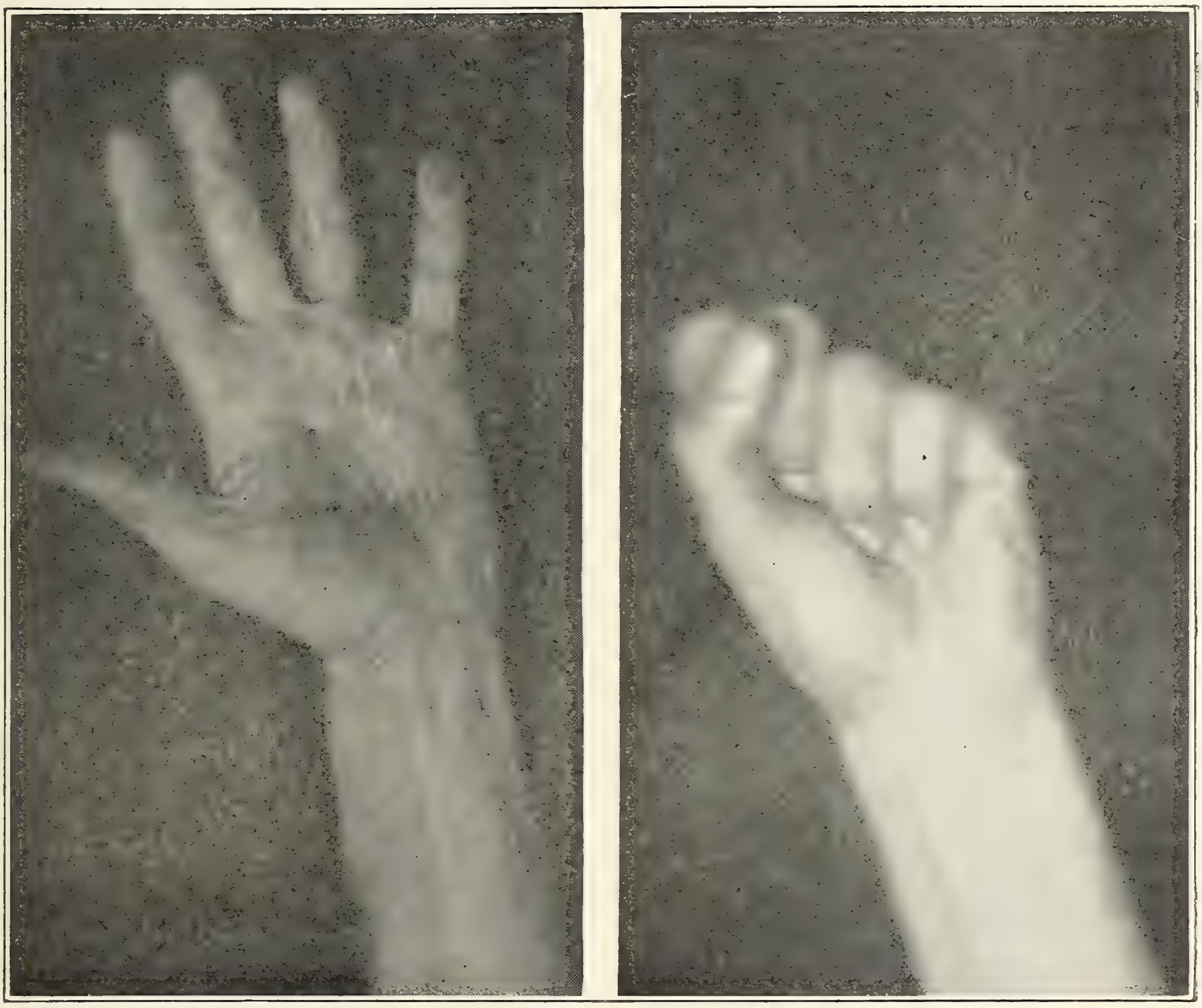

Figure 15 (*a* and *b*). End result of a suppurative tenosynovitis of the ring finger operated upon 12 hours after the onset of symptoms. Streptococcus hemolyticus cultured from the fluid. The segmented incisions are indicated. There is a return of complete function.

The diagnosis of this disease, especially in the early stages, may be exceedingly difficult. The writer feels that whenever doubt exists, provided that there is no tendon sheath or fascial space infection on the front of the hand, an exploratory operation over the suspected region is indicated. This disease is usually mistaken for an erysipelas. Once the infection has become fully developed, treatment consists in radical multiple incisions until the limit of the infection has been reached. These

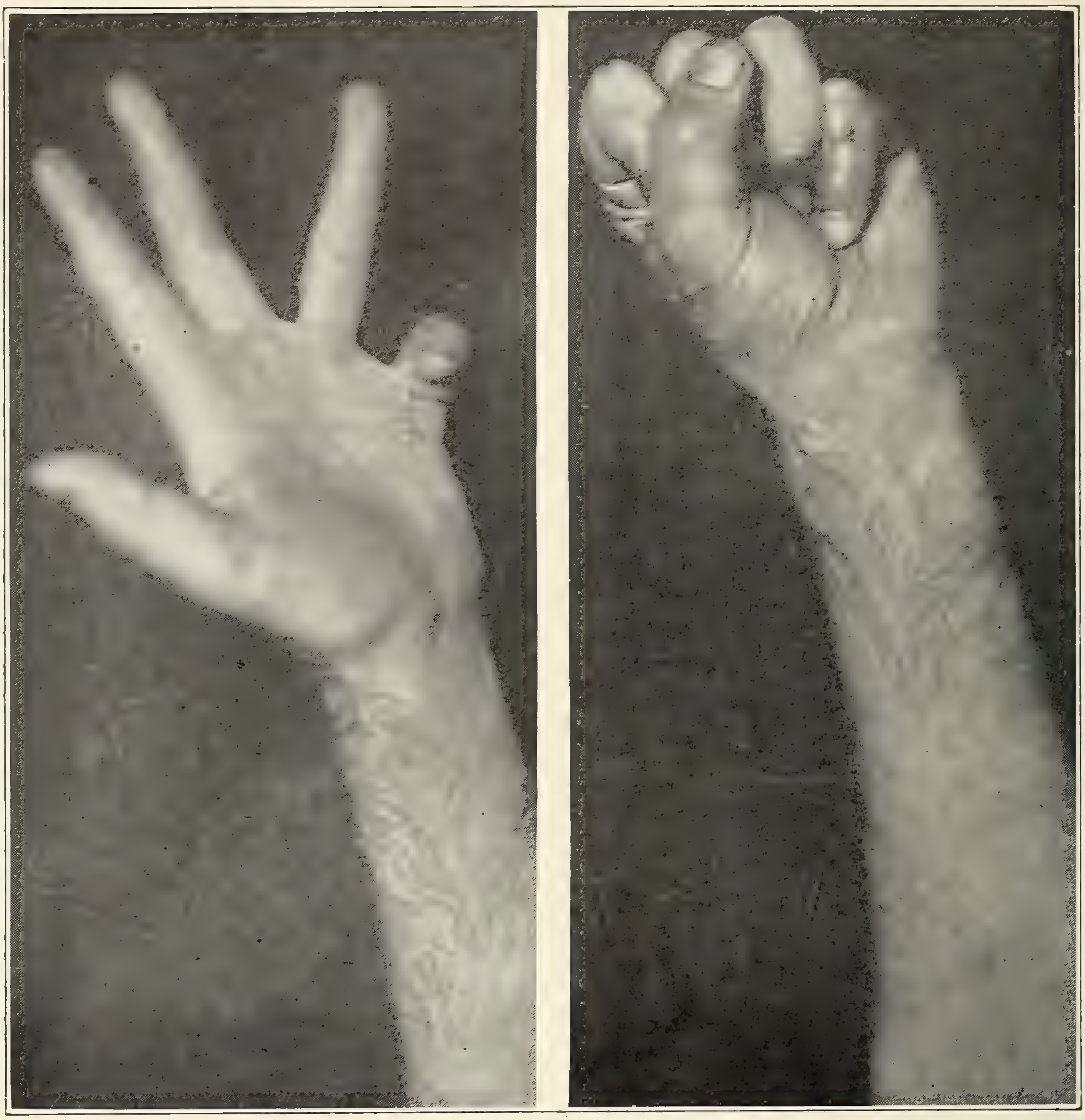

FIGURE 16 (*a* and *b*). These photographs illustrate what sometimes happens when the continuous incision already referred to is used for a suppurative tenosynovitis. This patient was operated upon approximately 36 hours after the onset of symptoms. The wound of entry was a small laceration over the proximal digital flexion crease. The pus cultured staphylococcus hemolyticus. The tendons did not slough. The patient left the hospital before the wound was completely healed and did not report for further treatment. The result is a marked flexion contracture. In using the continuous incision, care should be exerted to prevent this complication.

incisions should be spaced far enough apart so as to avoid impairment of skin circulation. It is in this type of hand infection that the employment of the Carrel-Dakin dressing has given the best results. It seems to control the infection once the incisions are made, to cause a rapid separation of sloughs and to develop clean healthy granulation tissue. I feel that it materially shortens convalescence in this particular disease.

At this time it seems apropos to say a word about the use of the Carrel-Dakin treatment in hand infections in general. I have always been loathe to employ it in the treatment of tendon sheath infections, especially in the light of its effect on the peritoneum. In infections of fascial spaces, it is doubtful whether it is necessary because after a properly placed radical incision has been made, prompt recovery follows. I do not believe that convalescence has been shortened in those cases in which I have used the Carrel-Dakin treatment. In hand infections, I believe main reliance should be placed upon early diagnosis and properly placed radical incisions with careful attention to the numerous essential postoperative details.

WOUNDS OF TENDONS OF THE HAND

Many injuries of the hand which produce a solution of continuity of the skin, involve the tendons also. Every laceration or incised wound of the hand calls for a careful examination of active flexion and extension of all the finger joints. I feel certain, that if this were done consistently, and operation for the repair of a divided tendon were performed as an emergency soon after the receipt of the injury, we would see fewer and fewer hand disabilities in a class of patients who depend upon proper hand function for a livelihood.

It is to be remembered that the flexor tendons possess a most delicate and, at the same time, an exceptionally efficient gliding mechanism, the surrounding tendon sheath and the vaginal ligaments over the front of the proximal and middle phalanges and the heads of the metacarpal bones. The slightest injury to the endothelial lining of the surfaces of the tendons and the visceral aspect of the sheaths produces a marked reaction. Adhesions quickly form and bind tendon to sheath. The extent of this reaction is directly dependent upon the extent of the trauma to the structures. Therefor, in all operative work upon these delicate tissues, our technique must be practically atraumatic. One must not think of macroscopic trauma, but should always consider microscopic injury. This attitude toward the surgery of the flexor tendons may very well be applied to other problems in hand surgery. It is an ideal toward which every surgeon who attempts repair of tendons or reconstruction work in the hand must strive for. In the first place, every possibility for tremor must be eliminated. The patient's hand should be fixed to the operating table in such a way as to prevent the slightest possible movement. In operating, the surgeon himself should be comfortably seated with his forearms firmly braced against the table over which he is working. Asepsis in the operating room and amongst the nurses and assistants must be of the most rigid sort. To diminish the trauma incident to the operation itself, one should work in a bloodless field. This can be obtained by the proper application of an Esmarch bandage. If applied correctly, one need have

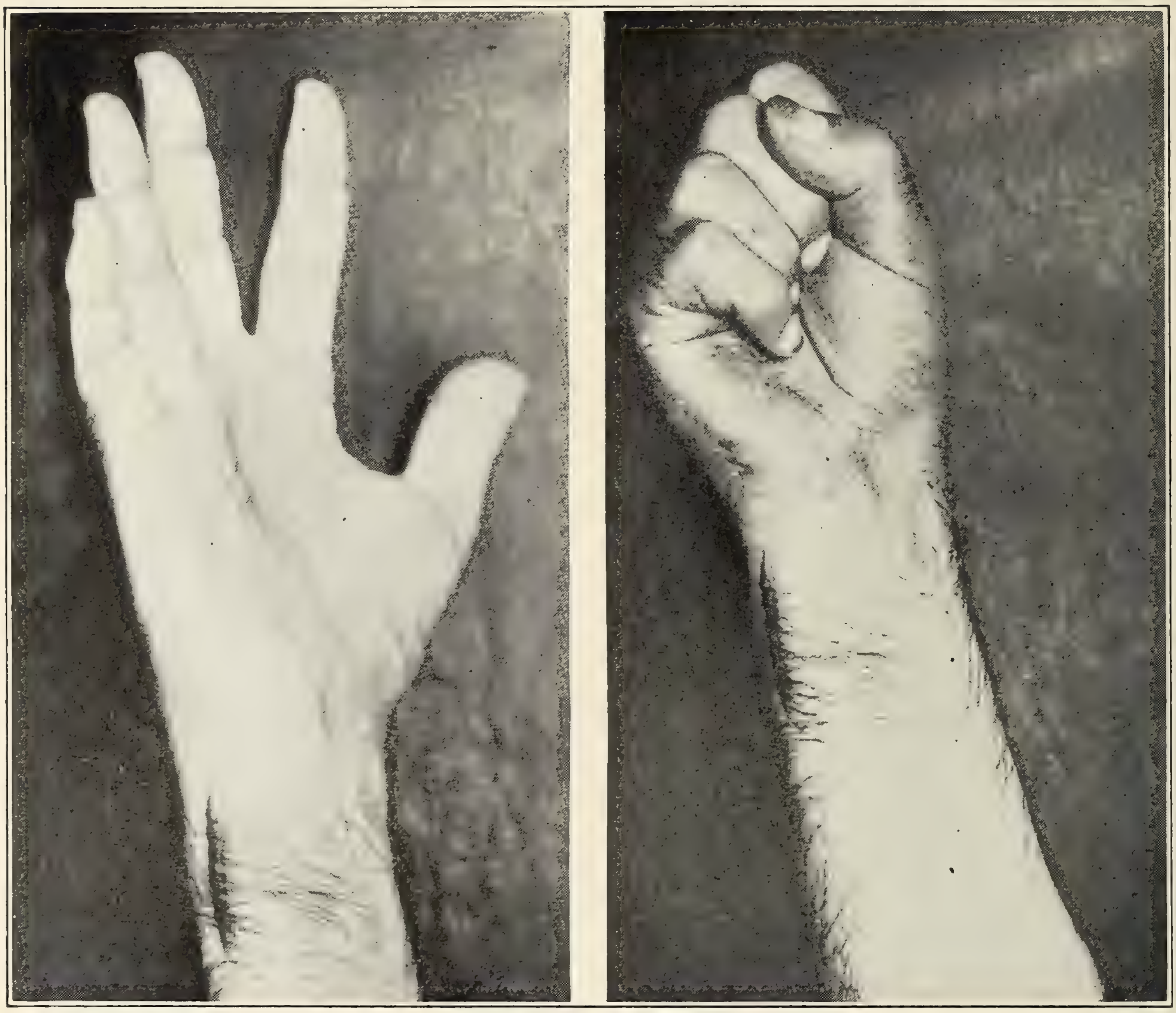

Figure 17 (*a* and *b*). End result in a case of acute suppurative tenosynovitis of the flexor tendon sheath of the little finger with involvement of the ulnar bursa and its prolongation above the anterior annular ligament. Operation was performed 48 hours after the onset of symptoms. Pus cultured streptococcus hemolyticus. The photographs indicate the lateral digital incision, the palmar incision to drain the ulnar bursa, and the internal lateral incision above the wrist. At the end of four months, there is return of complete function.

little fear in the use of this valuable aid to hand surgery. With the hand held in the elevated position for a few minutes, the Esmarch bandage is started at the finger tips and rolled down the arm, each turn being pulled as tightly as the rubber will permit, and overlapping the turn of the bandage that preceded it. In working on the hand, one need go no further with the bandage than the upper third of the forearm. Before the bandage is started, the hand and forearm should be wrapped in a single layer of sterile towel. At the point where it terminates, the toweling should be of four or five thicknesses so as to avoid the direct pressure of the bandage on the skin. Should it be found necessary to extend the bandage to the upper arm, the underlying towel ought to be folded over so as to have six or eight thicknesses. The Esmarch may either be left in this position until the close of the operation, or a blood pressure cuff may be applied to the arm above the termination of the Esmarch which may be removed after the blood pressure apparatus has been pumped up to about two hundred and fifty mm. of mercury. The surgeon should try to complete his operation within the period of one to one and a

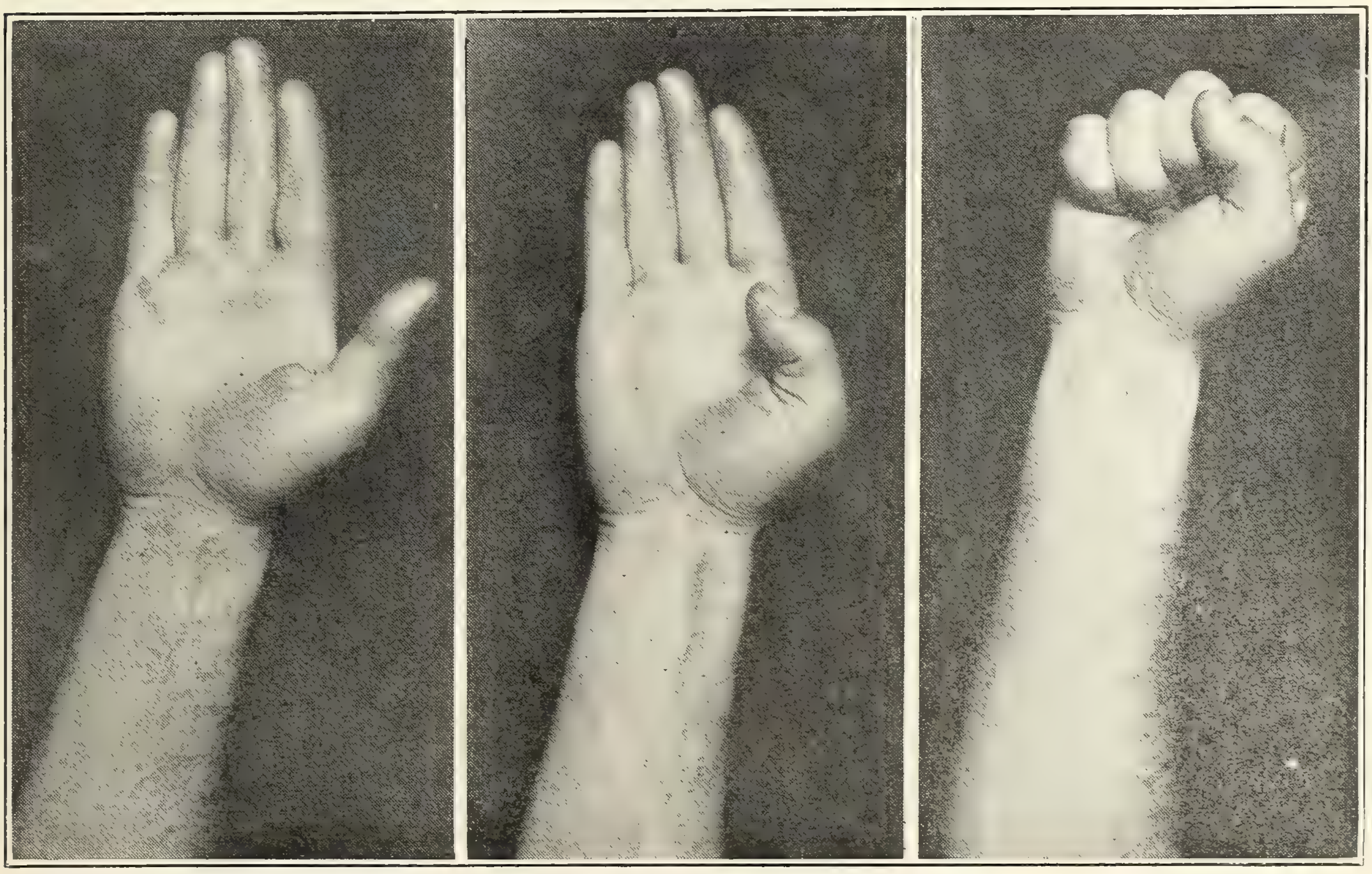

FIGURE 18 (*a*, *b*, and *c*). End result in a case of acute suppurative tenosynovitis of the flexor tendon sheath of the thumb with extension to the radial bursa and involvement of this structure as far as its upper prolongation above the wrist. Operation was performed approximately twenty-four hours after the onset of symptoms. The cause was a small wound in the distal flexion crease. Streptococcus hemolyticus was cultured. The photographs at the end of one year indicate the return of complete function. The lateral incisions at the wrist and in the hand proper are shown.

quarter hours. If he feels that the operation will be a long one, the additional use of the blood pressure cuff is indicated. During the course of a prolonged operation, the pressure in the apparatus may be diminished for a few seconds and then raised to its previous reading. This may be done every fifteen or twenty minutes. For an ordinary primary tenorrhaphy this is rarely indicated because the operation usually consumes less than an hour. I have never seen a musculospiral paralysis following the use of an Esmarch bandage as described.

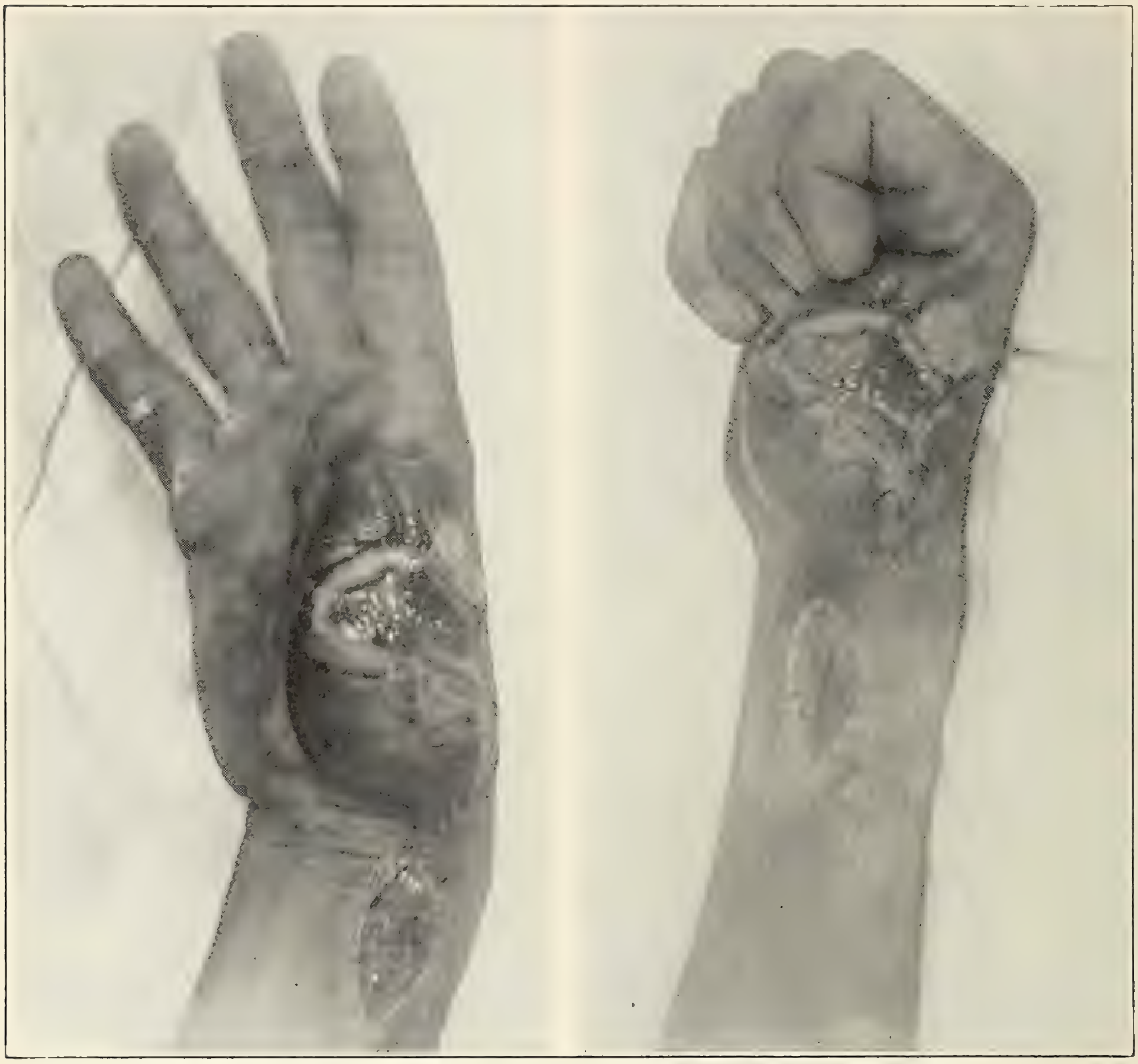

FIGURE 19 (*a* and *b*). These photographs illustrate what sometimes happens in traumatic amputations of the thumb. A radial bursitis developed which was drained through the amputation stump and by an internal lateral incision above the wrist. The extent of active flexion of the remaining fingers on the third postoperative day is noteworthy.

In the performance of the actual operation, all tissues must be handled with as great gentleness and delicacy as possible. One must always maintain a wholesome respect for tissues and keep one's mind on their postoperative reaction. This is applicable to skin as well as subcutaneous tissues, muscles, tendons and nerves. Instruments should be the sharpest obtainable and small in size. One must avoid heavy catgut, large knots, dead spaces, tension of sutures, mass ligation, too many stitches, foreign bodies in fat, closure with incomplete hemostasis, the use of very hot sponges and drying of the tissues due to prolonged exposure. In tying off bleeding points, the finest catgut should be used. The reduction of the time of operation to a minimum may be obtained by good team work, conservation of movements, the elimination of unnecessary puttering and a proper exposure of the field of operation. The foregoing is a prime requisite if one is to expect good results in the surgery of the tendons, of the nerves, and skin plastics of the hand.

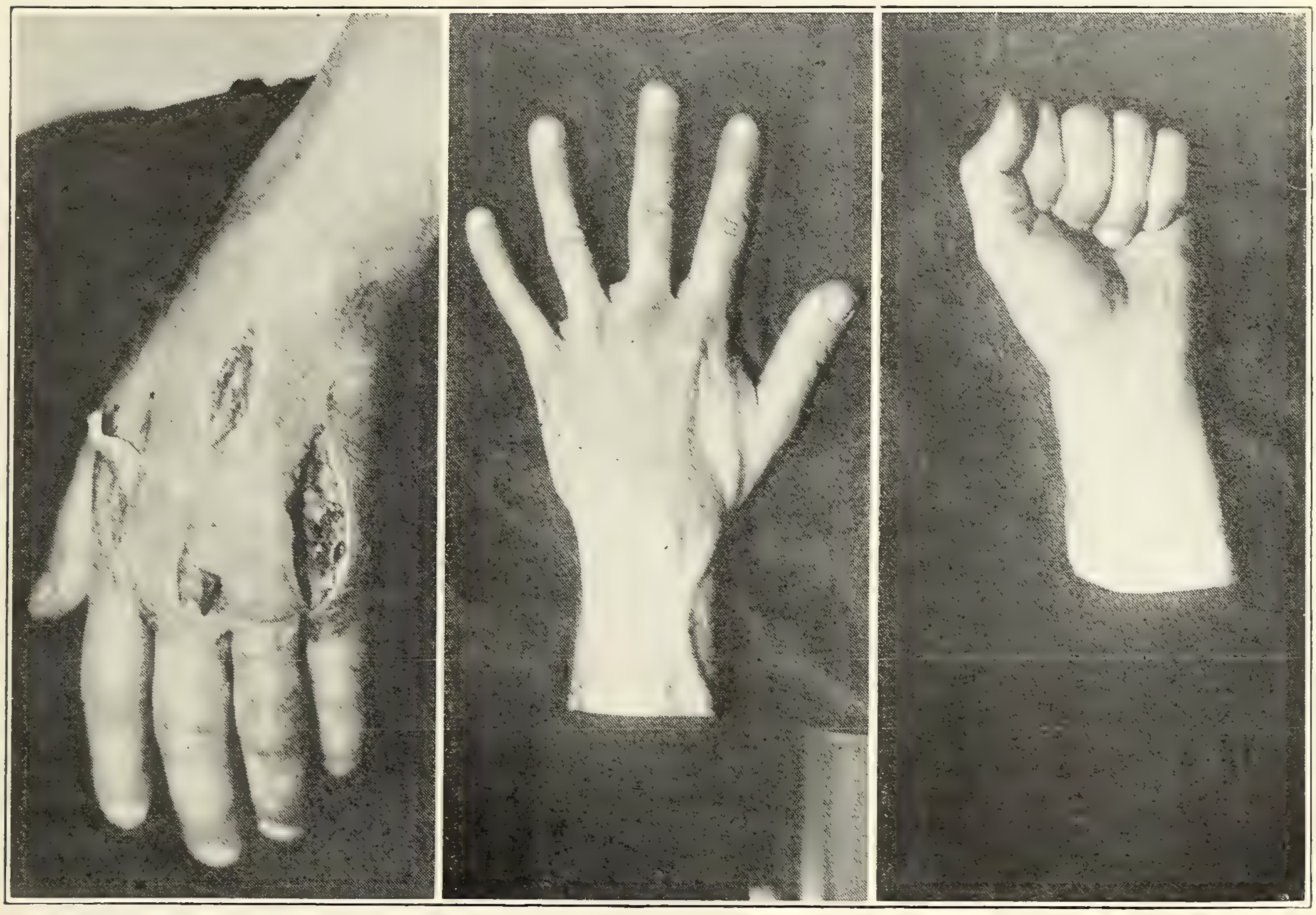

FIGURE 20 (*a*, *b*, and *c*). This photograph represents an extensive virulent infection on the dorsum of the hand involving the dorsal subcutaneous and subaponeurotic spaces. The patient, a policeman, received a laceration over the knuckle of the middle finger when he hit a prisoner in the mouth. 24 hours later, he became profoundly ill with enormous swelling of the back of the hand. Temperature variations ranged between 100° F. and 104.5° F. At operation, radical incisions were made, draining the entire dorsum of the hand. Photograph was taken on the 6th postoperative day. Complete restoration of function was obtained, as indicated in the additional photographs taken six months later.

Flexor tendons. With the diagnosis of a divided flexor tendon made,

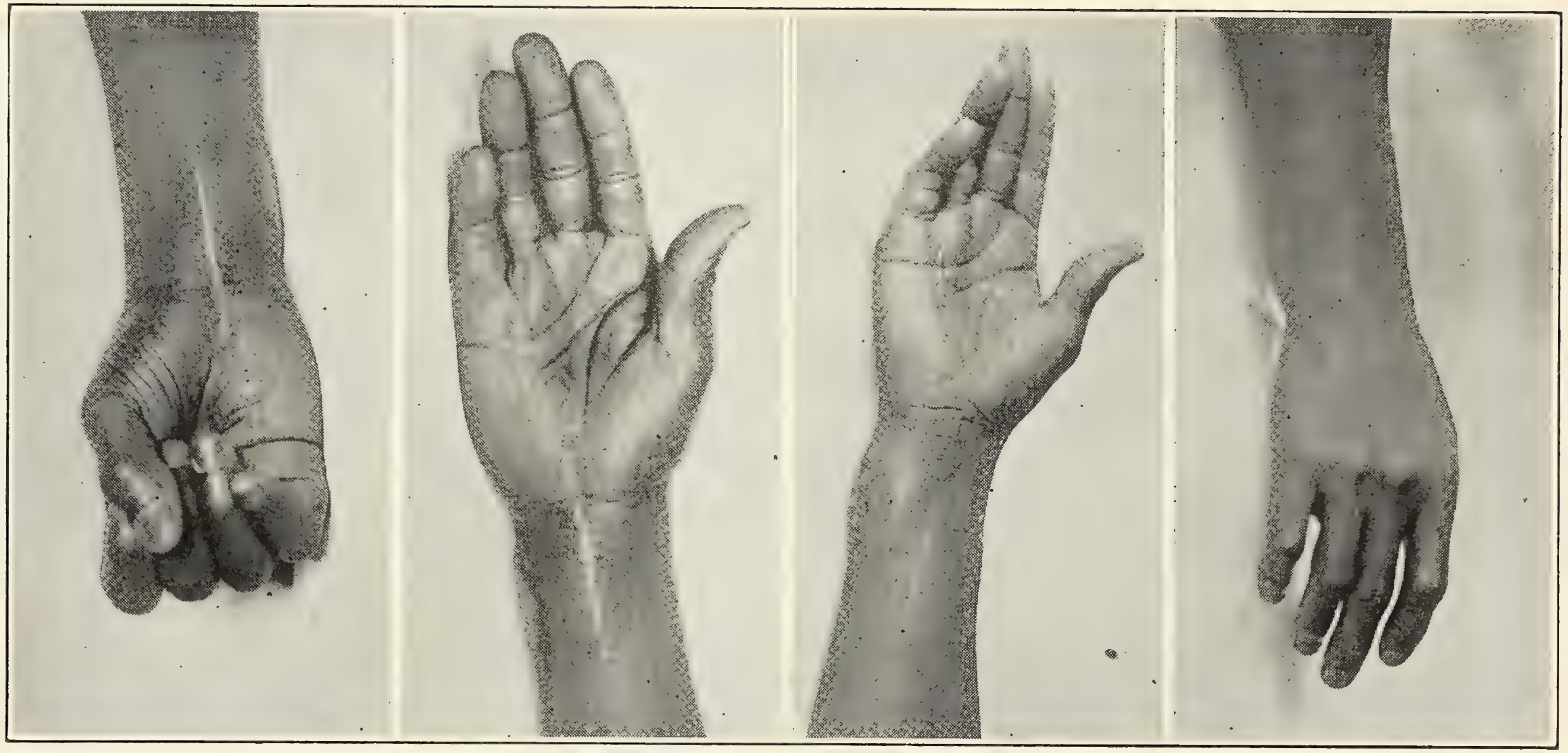

Figure 21 (*a*, *b*, *c*, and *d*). These photographs represent a case of tuberculosis of the flexor tendon sheath of the little finger and ulnar bursa. A year and a half before the onset of this illness, the patient was operated upon by the writer for a suppurative tenosynovitis of the flexor tendon sheath of the little finger, complicated by an ulnar bursitis. Streptococcus hemolyticus was cultured. Following operation, there was return of complete function. A year and a half later, he re-entered the hospital with a history of swelling of the wrist and palm, with tenderness and limitation of motion in the little and ring fingers. Examination disclosed an ovoid swelling over the inner side of the wrist with fulness in the palm. The swelling was doughy and slightly tender. A radical operation which included a long median incision splitting the annular ligament was performed. The entire ulnar bursa was thickened, greyish red in color, and extremely vascular. The tendon sheath of the little finger was free from pathology. The entire ulnar bursa was excised. Iodoform powder was rubbed into the tissue and the wound was closed without drainage. The wound healed by first intention. A guinea pig inoculated with the tissue, showed evidence of tuberculosis. Final result is shown in the photographs.

Tuberculosis of the flexor sheaths and bursae of the hand is not uncommon. The treatment consists in radical excision of all involved structures and the institution of early active motion.

operation for its repair should follow soon after the receipt of the injury. (See Figure 22.) In the vast majority of cases this can safely be done provided that, at operation, the original wound is carefully and completely debrided. After the administration of an anæsthetic, the skin of the hand and forearm should be prepared thoroughly. This entails first a careful scrubbing with sterile soap and brush, followed by irrigation with saline. Great care should be exerted to prevent washing debris and soap suds into the original wound. After careful drying, the skin is washed off with benzine followed by ether. The extremity up to the elbow is then painted with three and a half per cent. iodine, care being exerted to prevent the entrance of any iodine into the tendon sheath. When, however, the wound is found before operation to be ragged and dirty, obviously grossly contaminated, and the surrounding skin is covered with grime and dried blood, and there has been considerable crushing of the tissues in addition to laceration, I feel that the repair of the tendon should be deferred until the wound has healed, the immediate interference consisting solely in a general cleansing and debridement. Two or three weeks later, one may safely undertake the repair of the tendon in a clean field. In the presence of all other wounds within the initial twelve hours following the injury, immediate tenorrhaphy can be done with safety after the skin cleansing already described.

The site of incision for exposure of the ends of the divided tendon or tendons will depend upon the situation of the original wound. The accompanying diagram (See Figure 22.) illustrates more graphically than words where these incisions should be placed in each instance. The important point to remember is that the incisions should always be made on the lateral aspect of the finger. Making a median longitudinal incision is a pernicious practice because the subsequent healing is bound to produce a flexion contracture. In the palm, the incision should be lateral to the anatomical position of the tendon to be repaired. If the flexor profundus tendon has been divided at about the center of the middle phalanx, its proximal end will retract to about the region of the proximal digital flexion crease, being prevented from retracting further by the vincula tendineæ. Instead of extending the lateral incision down to this point, a transverse incision may be made in this crease and through a small transverse opening in the tendon sheath, the retracted end may be isolated and threaded through the remainder of the sheath after the suture has been inserted. By this manoeuvre, one diminishes the operative trauma and also preserves the vaginal ligaments of the tendon sheath. If the original wound is located over the front of the proximal phalanx, one or the other or both of the flexor tendons may be divided. The lateral incision is here also used, but its proximal end should not extend beyond the proximal digital flexion crease, because it has been found that, if this is done, the chances for the development of a flexion contracture are greatly enhanced. Very often, because of the attachment of the vincula tendineæ, it will be found that the proximal ends of the divided tendons are very close to the original wound. Should they be found to be retracted, a separate transverse incision may be made in the palm. Every effort should be made to preserve the integrity of the vincula tendineæ be-

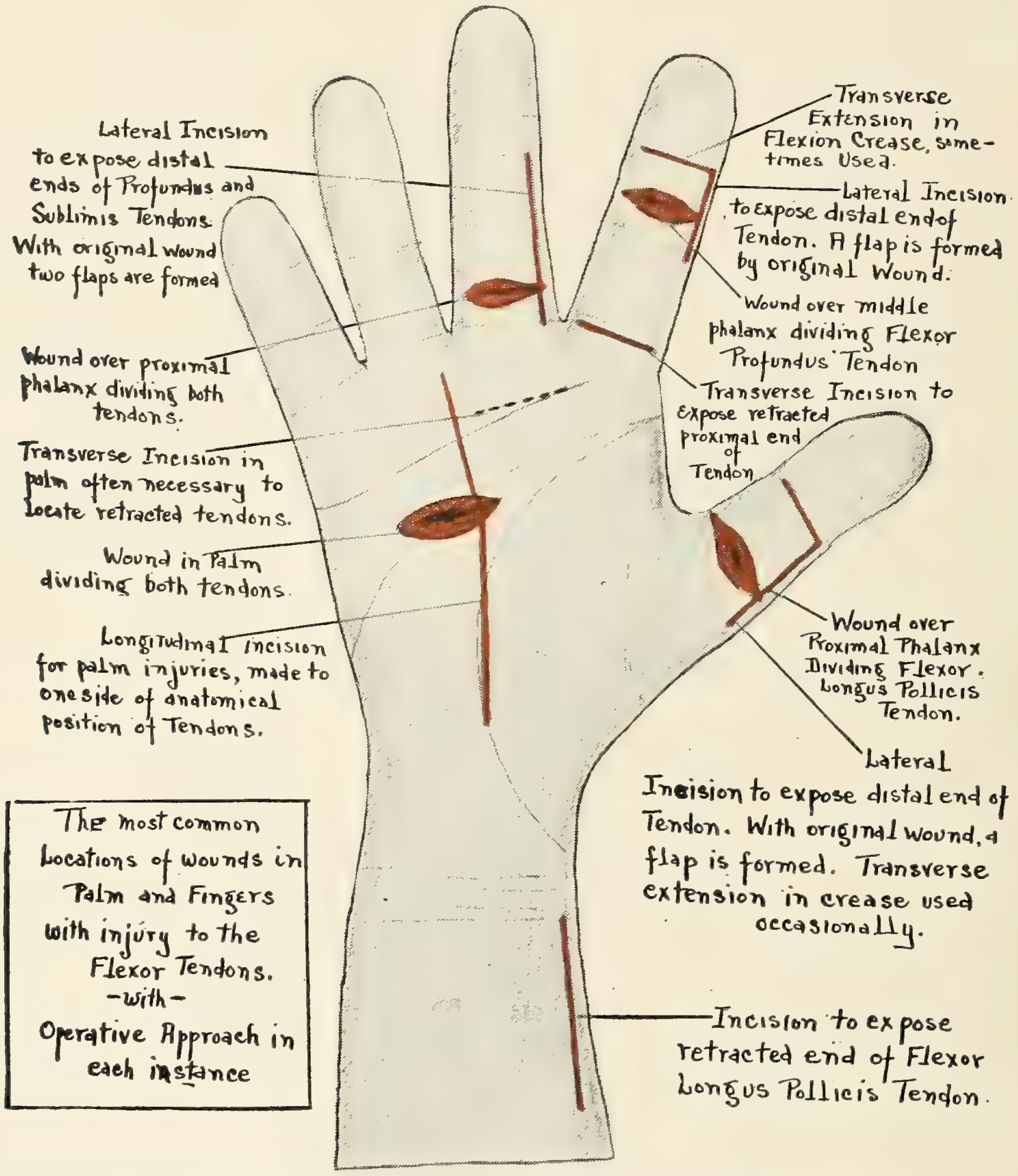
Lateral Incision to expose distal ends of Profundus and Sublimis Tendons. With original wound two flaps are formed
Wound over proximal phalanx dividing both tendons.
Transverse Incision in palm often necessary to locate retracted tendons.
Wound in Palm dividing both tendons.
Longitudinal incision for palm injuries, made to one side of anatomical position of Tendons.
The most common Locations of wounds in Palm and Fingers with injury to the Flexor Tendons. -with- Operative Approach in each instance
Transverse Extension in Flexion Crease, sometimes Used.
Lateral Incision to expose distal end of Tendon. A flap is formed by original Wound.
Wound over middle phalanx dividing Flexor Profundus Tendon
Transverse Incision to expose retracted proximal end of Tendon
Wound over Proximal Phalanx Dividing Flexor Longus Pollicis Tendon.
Lateral Incision to expose distal end of Tendon. With original wound, a flap is formed. Transverse extension in crease used occasionally.
Incision to expose retracted end of Flexor Longus Pollicis Tendon.

FIGURE 22. Drawing of the hand to indicate the most common sites of wounds in the fingers and palm, resulting in injury to the flexor tendons. The skin incisions are indicated in red. The transverse incision in the distal flexion creases is sometimes used to obtain complete exposure. This, however, is infrequently necessary. The original wound in the skin and subcutaneous tissues must be completely debrided before closure. Digital incisions must avoid the anterior surface of the finger and not cross flexion creases at right angles. Great care is to be exerted to maintain the integrity of the vaginal ligaments of the tendon sheaths.

cause it is through these structures that the tendons derive their blood supply. When the original wound is located over the proximal phalanx of the thumb it will be found that the proximal end of the flexor longus pollicis tendon has retracted to a point opposite the wrist joint. A separate side incision is here in order for the exposure of this part of the tendon which may then be threaded through the sheath after the silk

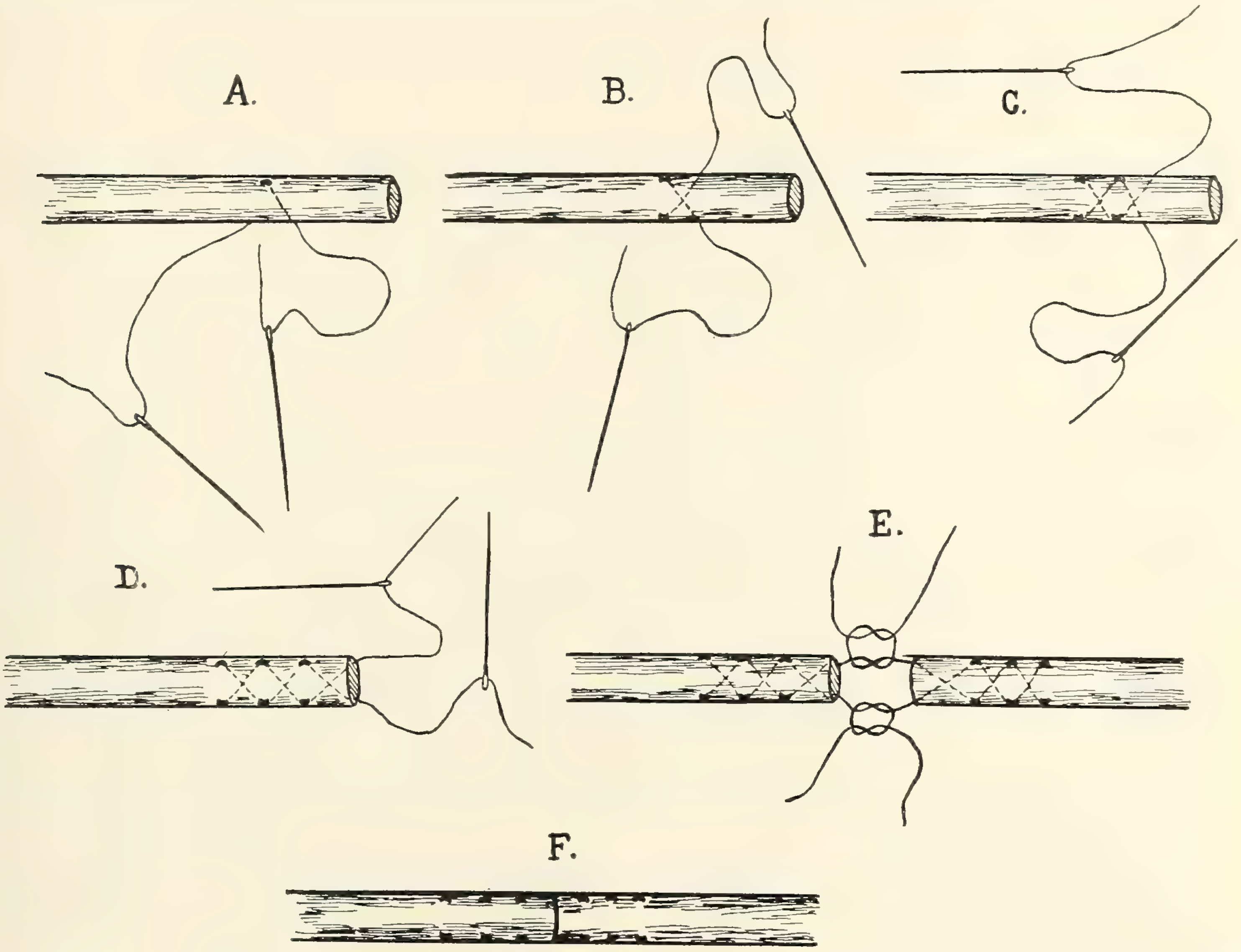

Figure 23. (*a*, *b*, *c*, *d*, *e* and *f*). Method used for the repair of divided tendons. At *A*, the suture material is passed transversely through the tendon about $\frac{1}{2}$ an inch from its extremity. Both ends of the suture which consists of fine silk, are threaded on fine straight needles. One of the needles is made to pass obliquely through the tendon, coming out on the opposite side. The other needle is passed through in a similar manner, coming out at the side opposite the point of exit of the first needle, *B*. This leaves a minimum of suture material on the surface of the tendon. The needles are then passed again obliquely through the tendon and made to come out at opposite sides, as shown at *C*. The needles are then passed again through the tendon and emerge at the tendon end near the periphery, as shown in *D*. It will be noted that a minimum amount of suture material lies exposed on the surface of the tendon. The same procedure is carried out in the other end of the divided tendon. When the knots are tied uniting the proximal and distal extremities of the tendon, it will be seen that they lie buried between the tendon ends, *E*. They should be tied in such a way as to cause "buckling" of the tendon at the site of repair, *F*. Before the knots are tied, the slack of the suture in the tendon must be "taken up" by pulling on the ends of the suture. Before the needles are made to emerge at the end of the tendon, a fresh accurate transverse extremity is produced by excising with a razor blade the end which has been held in an Allis clamp. Thus all traumatized tissue is excised before the repair is completed.

suture has been placed in its end, and joined to the distal end of the tendon.

In the actual repair of a divided tendon, I am thoroughly convinced that silk should be used. Some experimental work which I performed along these lines a few years ago, indicated that silk causes the least reaction and seems to remain as an innocuous foreign body in the substance of the tendon. (See Figure 24.) In addition, it permits of early active motion. The most efficient suture material for this purpose is Turner's patent ligature silk of about No. 3 or 4 size. Very fine short straight needles are used. The accompanying diagrams (See Figure 23) indicate the method of inserting the silk suture in the tendon ends. It will be seen that it is so placed as to be braided into the tendon. Before the emergence of the silk at the end of the tendon which has been held grasped by an Allis clamp, the contused part held by the clamp is excised by a very sharp razor blade so as to give a fresh non-traumatized end. When the corresponding ends of the silk in the two tendons are tied, it will be seen that the knots lie between the tendon ends and that there is accurate apposition of these two structures. This method of suture accomplishes two things. It produces a firm mechanical joining of the tendon ends and leaves a minimum amount of suture material on the

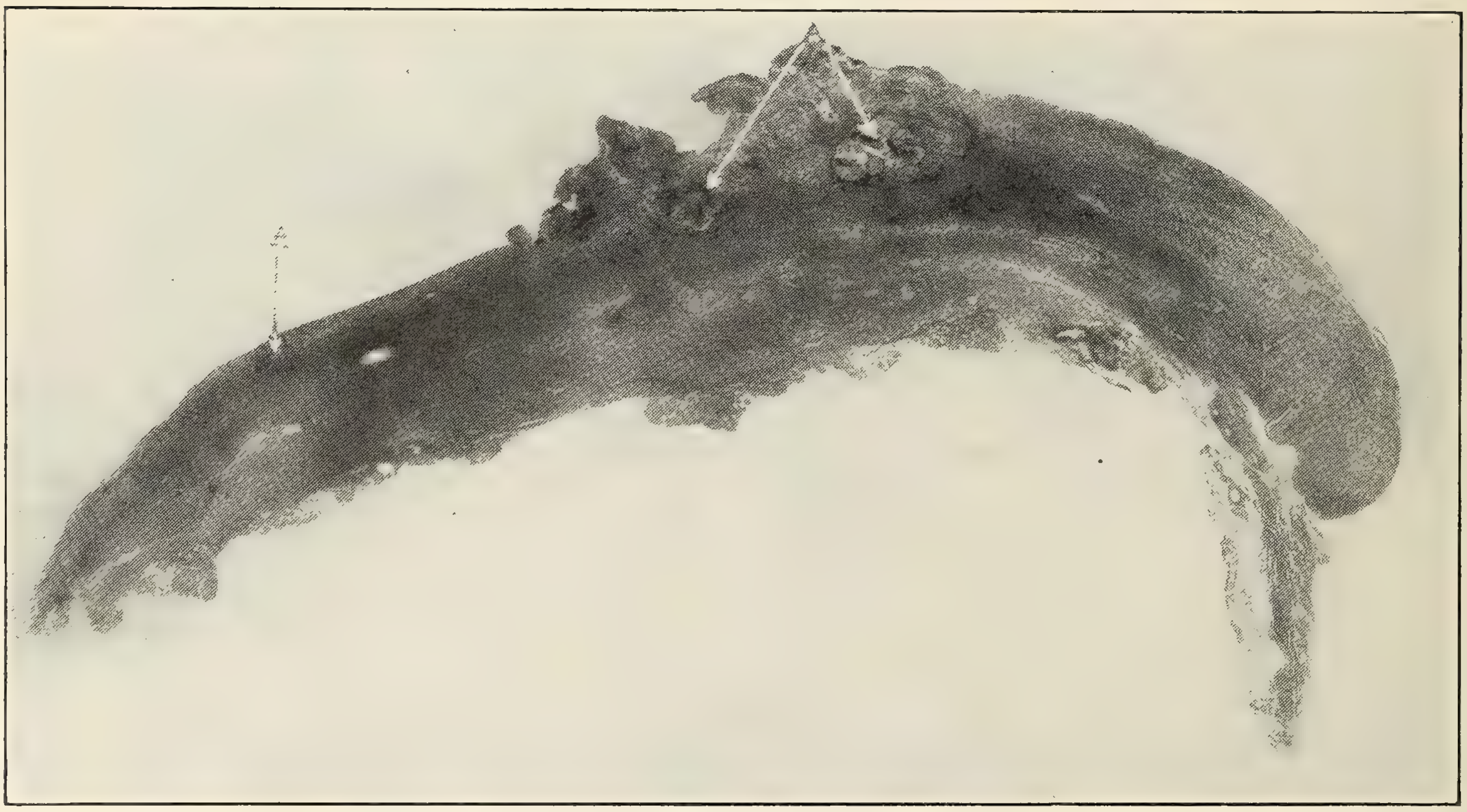

FIGURE 24. Photomicrograph of a section from a dog's tendon repaired by the method described under Figure 23. The immobilizing cast was removed on the 8th postoperative day. The specimen was excised on the 16th day. The suture material (silk) is visible at *A* and *A* prime. The firm union and the lack of any marked adhesions is noteworthy.

surface of the tendons, thus reducing the possibility for the formation of adhesions to a minimum. Following the repair of the tendon itself, the small wounds in the tendon sheath should be closed with interrupted sutures of the finest plain catgut. The Esmarch bandage is then removed and hemostasis carefully attended to. The wound must be thoroughly dry before the skin is closed with interrupted sutures of fine chromic catgut.

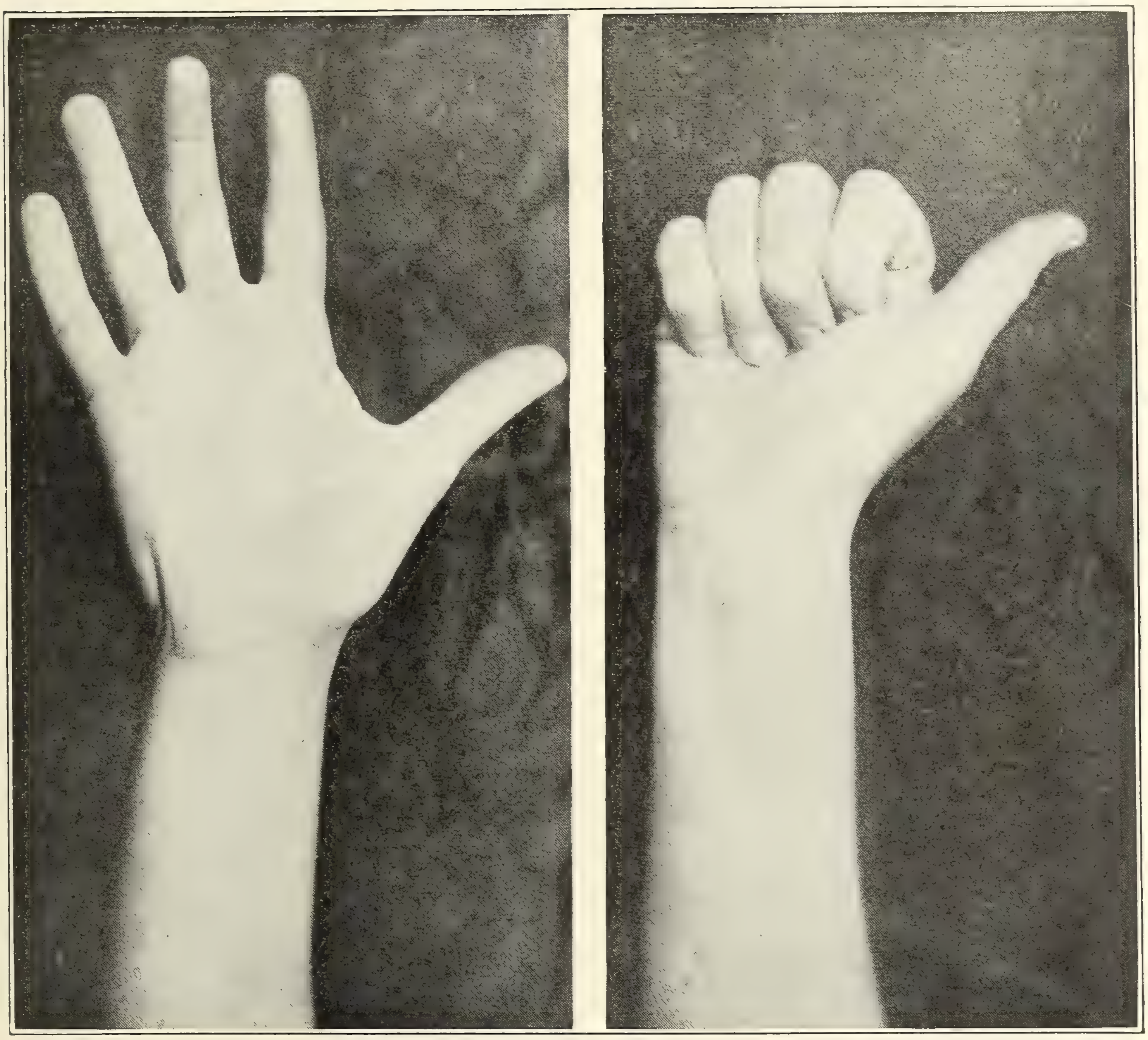

FIGURE 25. (*a* and *b*). Case illustrating division of the flexor profundus tendon of the right middle finger 1 c.m. proximal to its insertion. Because of extensive skin soiling, operation was deferred until 13 days after receipt of the injury, when the wound was completely healed. The technique as described in the text was followed. Active motion was instituted on the 7th postoperative day. Photographs indicate the result at the end of one year.

Following the application of the dressings, it has been my custom to apply a light plaster glove with the repaired finger and the wrist in acute flexion. From the experimental work already alluded to, it was found that active motion can safely be started on about the fifth or sixth postoperative day. Following this initial five day period, the splint is removed daily and the patient encouraged to actively flex and extend the finger *within the limits of pain.* On about the ninth or tenth day, the plaster glove may be discarded, and a dorsal metal splint applied so as to keep the wrist in acute flexion. Finger immobilization after this date seems unnecessary because by holding the wrist in flexion, one diminishes the intensity of contraction of the flexor muscles. This dorsal splint should be worn for a period of eighteen to twenty-one days, as determined by

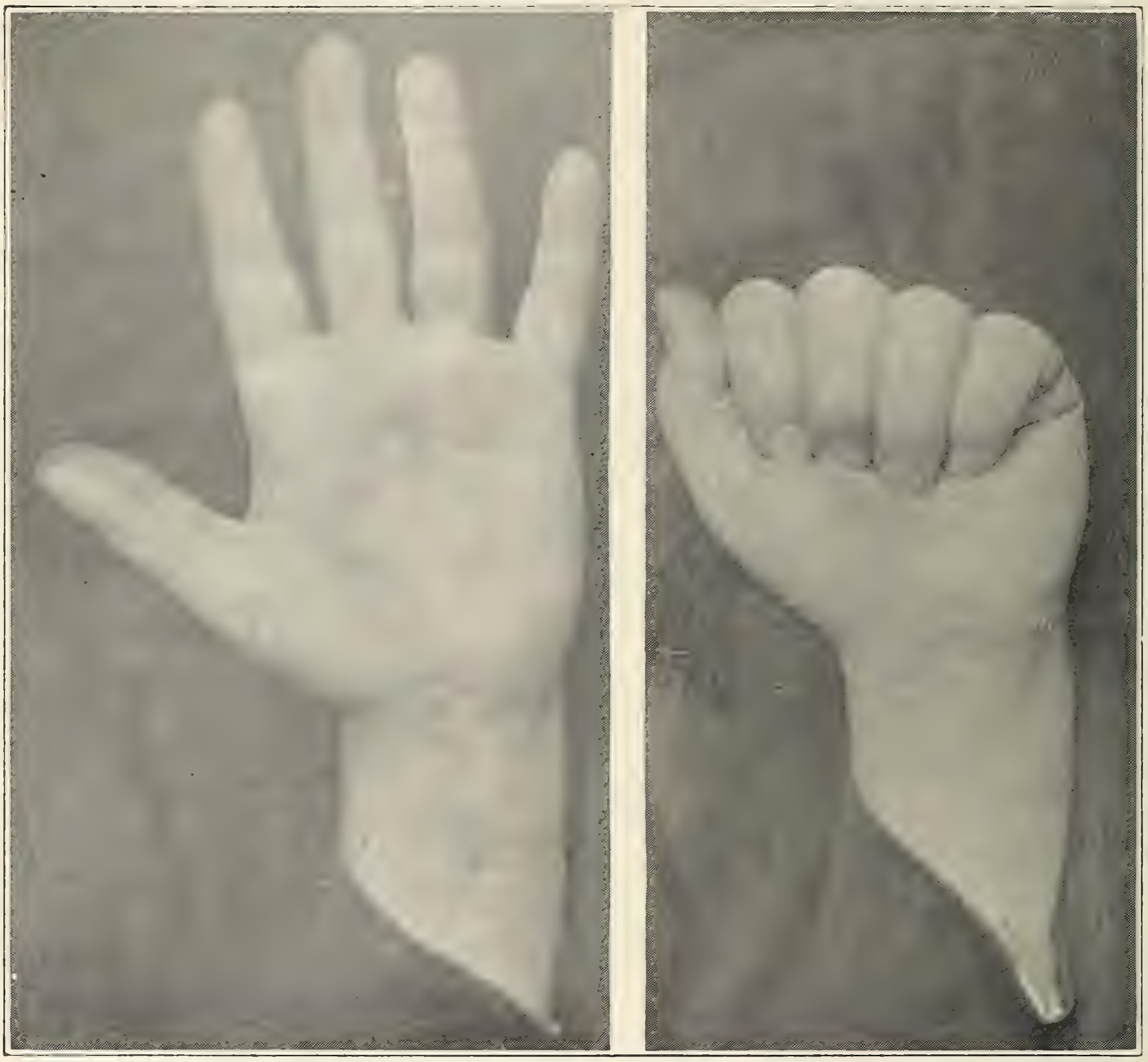

Figure 26. (*a* and *b*). Case to illustrate division of both flexor tendons of the left middle finger in the palm at the region of the outer end of the distal palmar flexion crease. Operation was performed 6 weeks after the injury. It will be noted that the incision is placed to one side of the anatomical location of the tendons. Active motion was instituted on the 8th postoperative day. Photographs were taken at the end of one year.

sections obtained from experimental animals. After this period, many other remedies may be utilized, as frequent strong galvanic stimulation of the muscles to produce strong contraction, thus helping to break adhesions, properly applied baking and massage, hot soaks, whirlpool baths, reeducation exercises, etc. While I do not question the value of these procedures and constantly make use of them, I feel that more can be accomplished by carefully controlled and personally encouraged daily active motion in the initial six or eight weeks of treatment. The time element

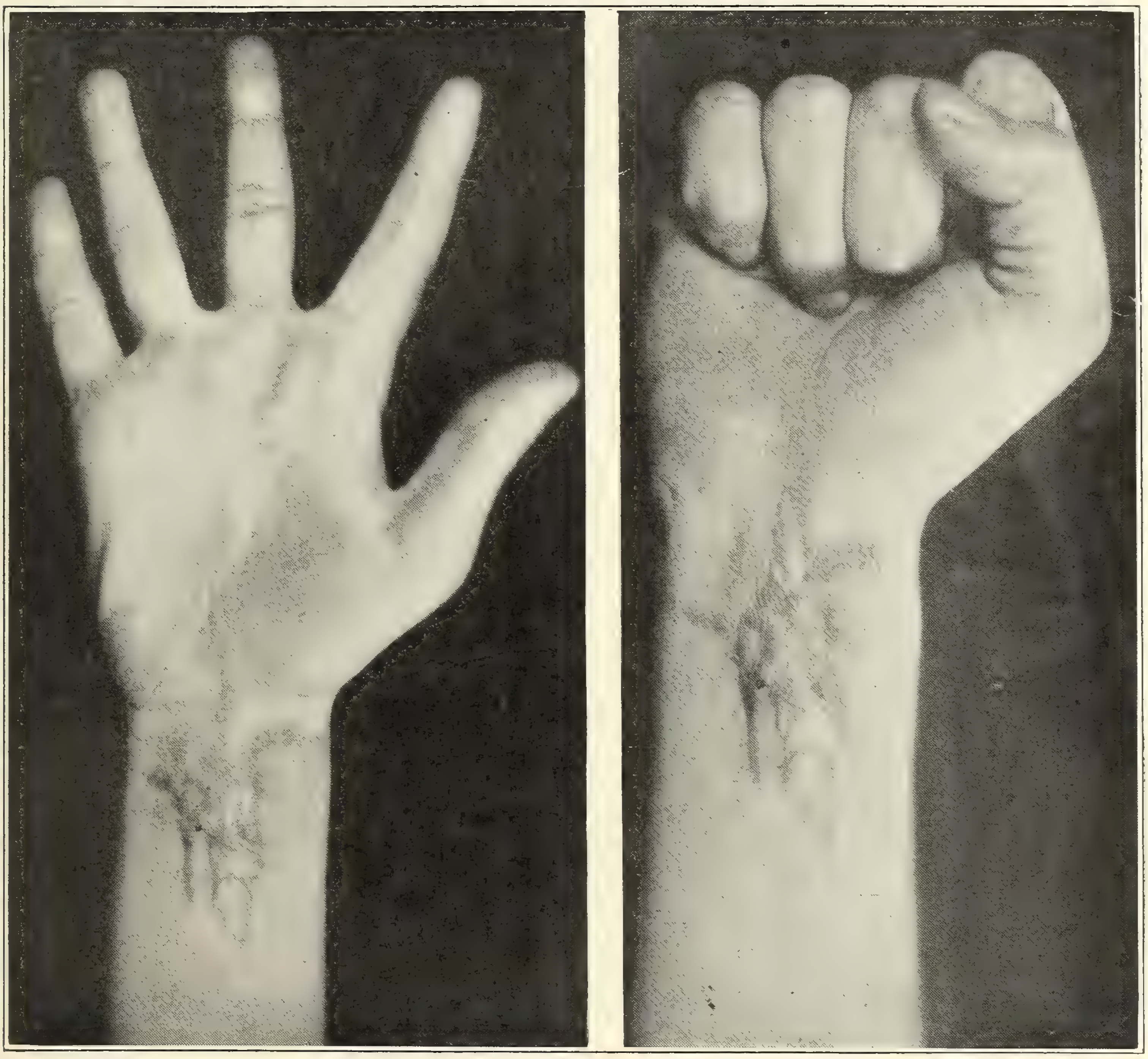

FIGURE 27. (*a* and *b*). Case to illustrate injury at the front of the wrist with division of all the flexor tendons and both the median and ulnar nerves. Operation was performed 3 hours after the injury, and consisted of a debridement and primary suture of all divided structures. Tendons were repaired by the technique described in the text. The nerves were repaired by inserting 6 perineural sutures of fine silk. Aside from a mild superficial skin infection, convalescence was uneventful. Active motion was instituted on the 10th postoperative day. The photographs indicate the result at the end of one year. The absence of atrophy in the hand muscles, indicating complete regeneration of the median and ulnar nerves, is noteworthy.

must also be considered as having a direct bearing on the eventual outcome inasmuch as an optimum result may not be obtained until a period of four to six or more months has elapsed. (See Figures 25, 26, and 28.)

A not uncommon injury is a laceration across the front of the wrist with division of most of the structures in this situation. Such an injury calls for a careful examination of the function of the small muscles of the hand and skin sensation of the extremity distal to the point of trauma so as to verify the presence or absence of injury to either the median or

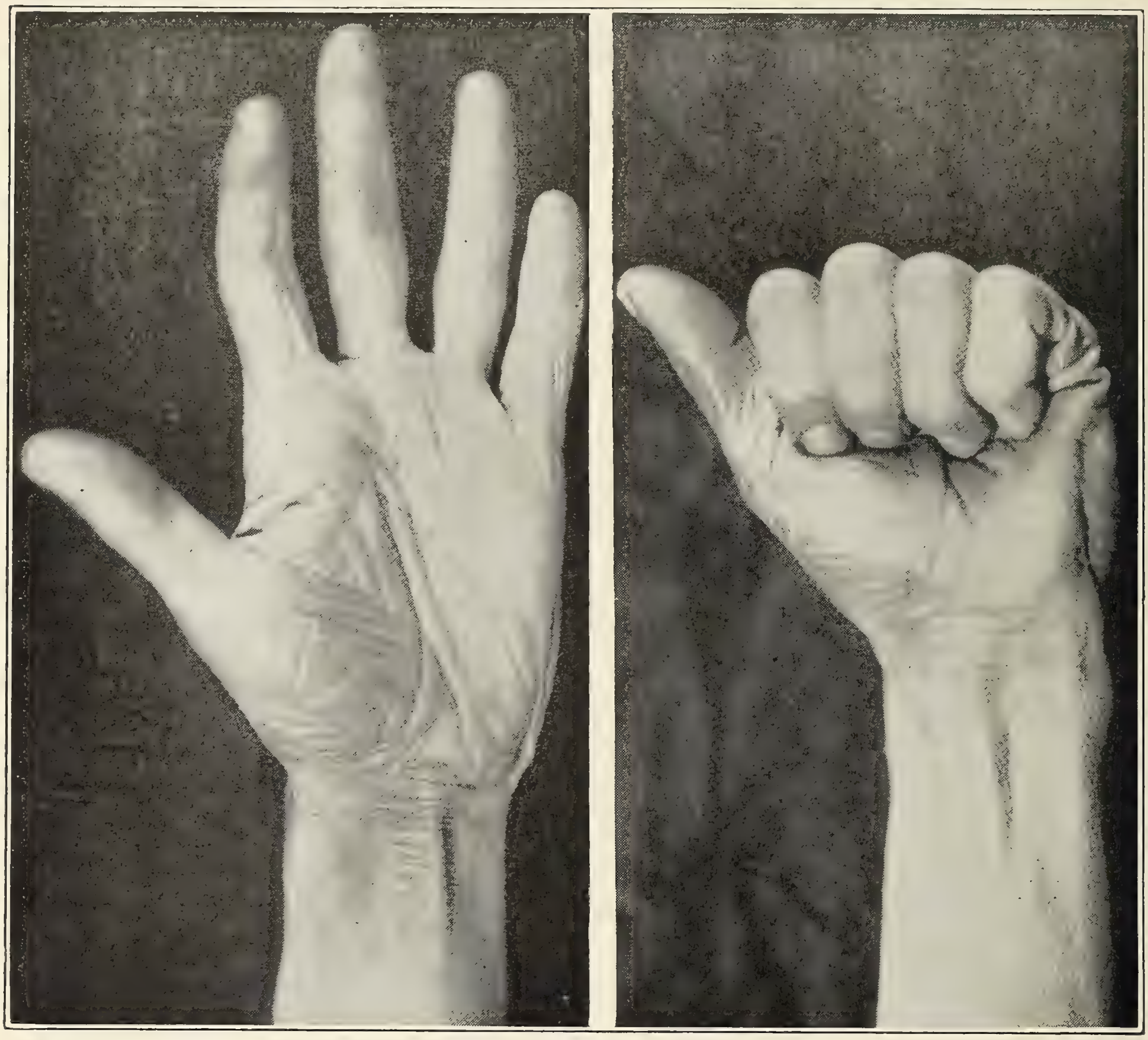

FIGURE 28. (*a* and *b*). This case illustrates two problems in hand surgery. The patient received a lacerated wound over the proximal digital flexion crease, caused by a buzz-saw. The finger was almost amputated. At operation both flexor tendons were found divided as were also both digital nerves of the index finger. The proximal phalanx was cut almost in two. Operation consisted in a thorough debridement and repair of all divided structures including the digital nerves. This operation was performed in 1923. The photographs at the end of 2 years indicate return of complete function. There is no interference of sensation in the finger indicating regeneration of the digital nerves.

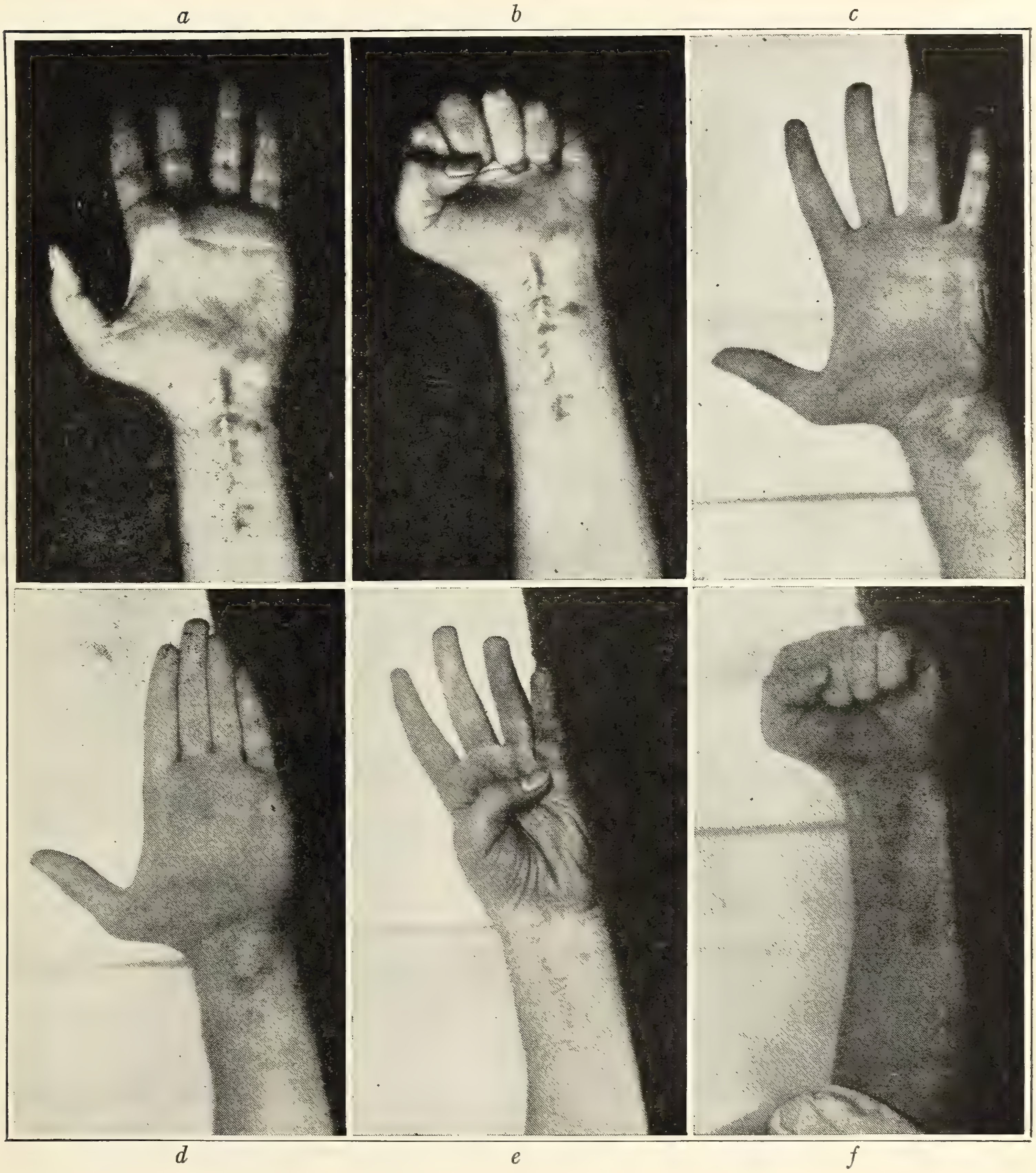

FIGURE 29. (*a*, *b*, *c*, *d*, *e* and *f*.) Case illustrating the early return of finger mobility after division of all the structures at the front of wrist. A complete debridement and repair was performed two hours after the injury. The photographs, *a* and *b* were taken at the end of seven weeks. Since that time there has been a complete regeneration of both the ulnar and median nerves, as indicated in the additional photographs. The normal fulness of the palm, abduction and adduction of the fingers in the extended position, and opposition of the thumb, should be particularly noted.

ulnar nerves or both. Not infrequently, it will be found that both these structures as well as all the flexor tendons have been divided by the trauma. It is a surprising fact that so many lacerations in this situation are treated by suturing the skin without any attempt to elicit the presence or absence of tendon or nerve injury.

The treatment of such an injury calls for immediate operation by a competent surgeon. A thorough knowledge of the anatomy of the structures in this region is necessary for the performance of an intelligent operation which is a tedious one. Following the preparation of the skin and the application of an Esmarch bandage as already described, the wound is completely debrided. A longitudinal incision proximal and distal to the original wound will be found necessary to locate the retracted ends of the divided structures. Repair of the tendons which must be accurately fitted together follows the same technique as already described. A divided median or ulnar nerve may be repaired by the insertion of five or six sutures of fine silk placed only in the perineural tissues and without disturbing the natural position of the two segments of the nerve by rotation of either one. On more than one occasion, I have seen the proximal end of a divided nerve sutured to the distal end of a tendon on the supposition that the nerve was tendon. With complete hemostasis, the wounds may be sutured without drainage. Postoperative treatment consists in placing the wrist and fingers in acute flexion and instituting active motion on about the fifth or sixth postoperative day. Flexion of the wrist should be maintained for a period of three or four weeks. As soon as possible, galvanic and faradic stimulation of the muscles supplied by the divided nerve should be resorted to, in order to lessen the atrophy that takes place. Complete regeneration of a divided nerve in this situation after the operative technique as described may not be evident before the expiration of twelve to twenty-four months. (See Figures 27 and 29.)

Extensor tendons. Injuries on the dorsum of the hand and fingers that involve division of the extensor tendons offer a much better prognosis as to return of function than those on the flexor aspect because of the absence of tendon sheaths over the major portion of the hand. The diagnosis is simple, and the treatment evident, following along the same lines as described under flexor tendons. When, at operation, the fascia extending between the various tendons is found divided, this should also be repaired because it strengthens the suture line in the tendon itself. A wound situated in the region of the posterior annular ligament divides the extensor tendon at the location of its tendon sheath. However, should adhesions form between the extensor tendon and its sheath at this point, the limitation of function will not be proportionately as great as when adhesions form between a flexor tendon and its sheath. In my experience, the surgery of extensor tendons following injuries, has given practically uniformly good results.

COMMON INJURIES OF THE HAND

The finger end. A frequent injury here is one involving a blow or a crushing force in the region of the nail. The delicate blood vessels in the subungual space rupture and a hematoma forms beneath the nail, lifting the body of the nail from the nail bed and matrix. The diagnosis is self-evident. It is an unusually painful injury and is immediately relieved by the evacuation of the subungual hematoma. This may be done by either boring a hole in the base of the nail or, better still, by removal of the entire nail base. To accomplish this, it is not necessary to make the side incisions as recommended in the treatment of paronychia. As time goes on, the newly formed nail, as it grows forward, pushes off the remains of the old nail, which very often may be removed before the growing new nail has reached it.

One of the most common injuries encountered in the finger end is a partial amputation through some part of the distal phalanx. Heretofore, the usual treatment for such a condition has been a reamputation usually involving the removal of the distal end of the middle phalanx and the fashioning of flaps " to cover over the end of the bone." By experience, however, it has been found that if these finger-end amputations are left alone, healing takes place with remarkably little visible loss of the digit. The initial treatment as I have practiced it in the past six or seven years, consists solely in a cleansing of the skin and the exposed wound, the removal of obviously dead tissue and the excision of whatever part of the phalanx protrudes beyond the soft part wound. All bleeding points are carefully ligated and the wound covered over with one layer of gauze lightly impregnated with vaseline. The events following this non-interference constitute an unusual chapter in the study of tissue repair. Granulations cover the exposed bone end and fill in the various crevices and defects that may be present. Epithelium then grows from the sides and soon covers the entire stump. The resulting scar occasionally may be tender but usually is not, thus forming a serviceable finger end. (See Figure 30.) The same method of treatment may be used often, after due consideration of the local conditions in each case, in amputations through other parts of the finger.

Lacerations. I bring up the subject of lacerations of the hand, solely to warn against the common practice of indiscriminate suturing. This

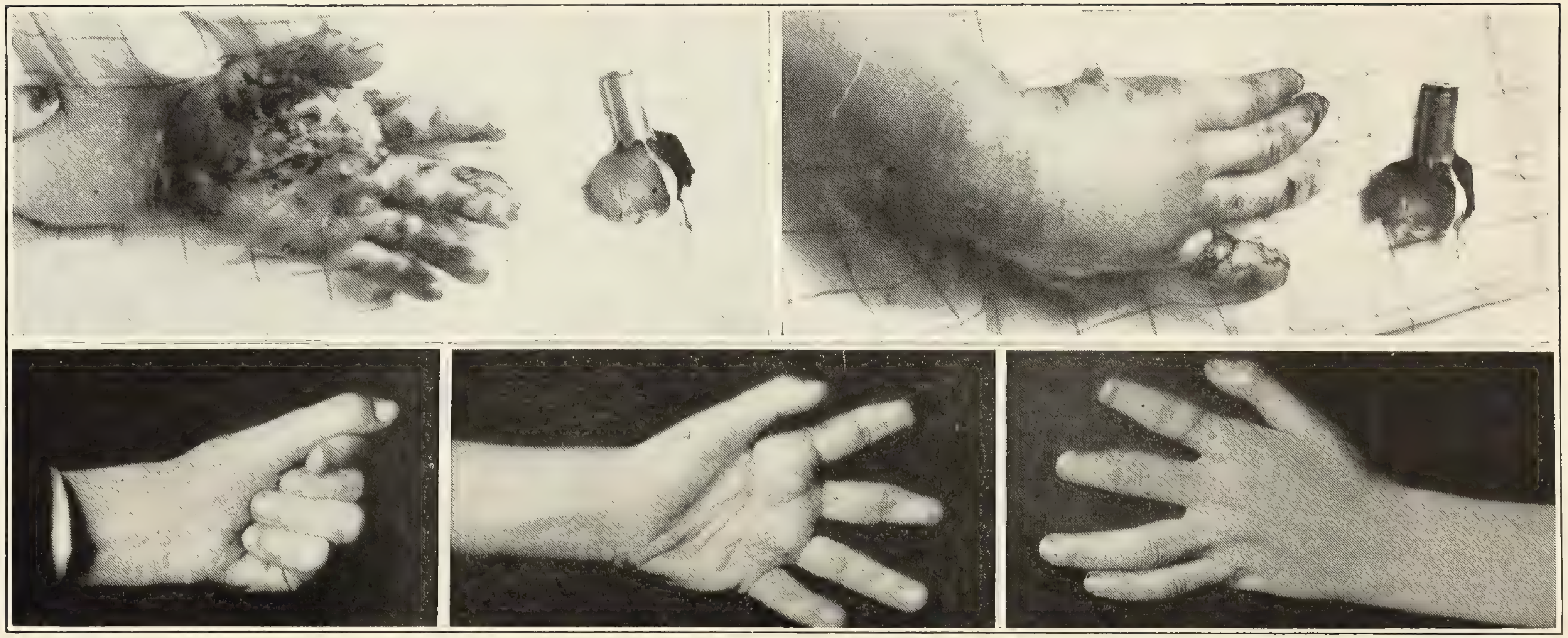

FIGURE 30. (*a*, *b*, *c*, *d* and *e*). This case illustrates a number of the problems involved in the treatment of common hand injuries. The patient, 7 years of age, discharged a 45 caliber cartridge into the palm of the left hand. The thumb was almost completely avulsed at the carpo-metacarpal joint. There was an irregularly shaped laceration along the adduction crease extending around to the back of the hand. The thenar muscles were pulpified. The flexor sheath of the thumb was open, but the tendon appeared intact. The first dorsal interosseous muscle was divided and crushed. The carpo-metacarpal joint was exposed and its capsule was practically completely divided. The thenar motor branch of the median nerve undoubtedly was destroyed. There were numerous lacerations on the thumb, one of them exposing the distal joint. The index, and middle fingers were partially amputated through the middle of the distal phalanges. Operation consisted of the preparation described in the text, followed by a complete debridement. The remains of the various thenar muscles were sutured. All the joint capsules were closed. The amputated ends of the middle and index fingers were dedrided and left wide open. The wound in the hand was closed without drainage. Convalescence was uneventful, and all wounds were healed within three weeks. The photographs were taken 5 days after operation and 10 months later. The complete healing with painless stumps of the index and middle fingers should be particularly noted. This case illustrates the rationale of the operation of debridement for extensive wounds of the hand. There is loss of power of opposition of the thumb because of destruction of the thenar muscles and the thenar motor branch of the median nerve. A tendon transplantation operation was suggested but refused.

applies especially to wounds on the flexor surface. If, however, the laceration receives the treatment already referred to, of careful skin preparation, and wound debridement soon after the receipt of the injury, then the situation is different, and the wound may be safely sutured. This, however, usually requires an anæsthetic and may not always be feasible. In the absence of such preliminary treatment, it is safer to content oneself with as thorough a cleansing as is possible under the circumstances, proper iodinization of the wound and surrounding skin, and the application of one or two strips of sterile adhesive so placed as to approximate the wound edges. In the fingers these strips of adhesive should never be applied so as to encircle completely a digit. Figure 31 indicates the end result in a hand which was subjected to the tight suture of a laceration over the anterior aspect of the middle finger at its junction with the palm. The result was a suppurative tenosynovitis of the flexor tendon sheath

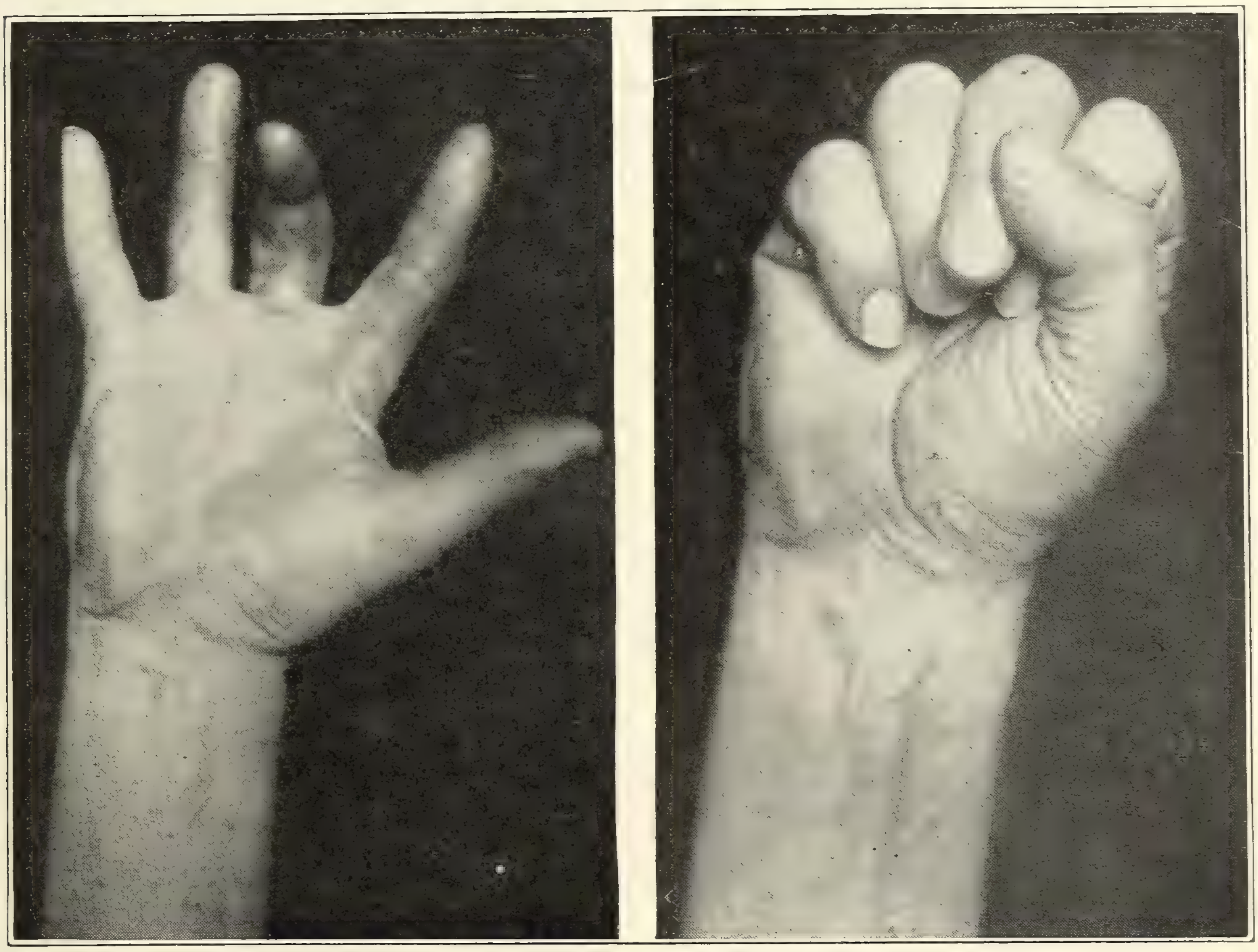

FIGURE 31. (*a* and *b*).This case illustrates what sometimes happens when wounds at the junction of the finger and palm are sutured tightly without preliminary debridement. This patient sustained a laceration over the front of the middle finger, and the palm, opening into the flexor tendon sheath. The wound was sutured tightly as a first aid dressing. A suppurative tenosynovitis developed and was operated upon approximately 50 hours later. The flexor tendons sloughed and contraction of the scar resulted in a flexion contracture.

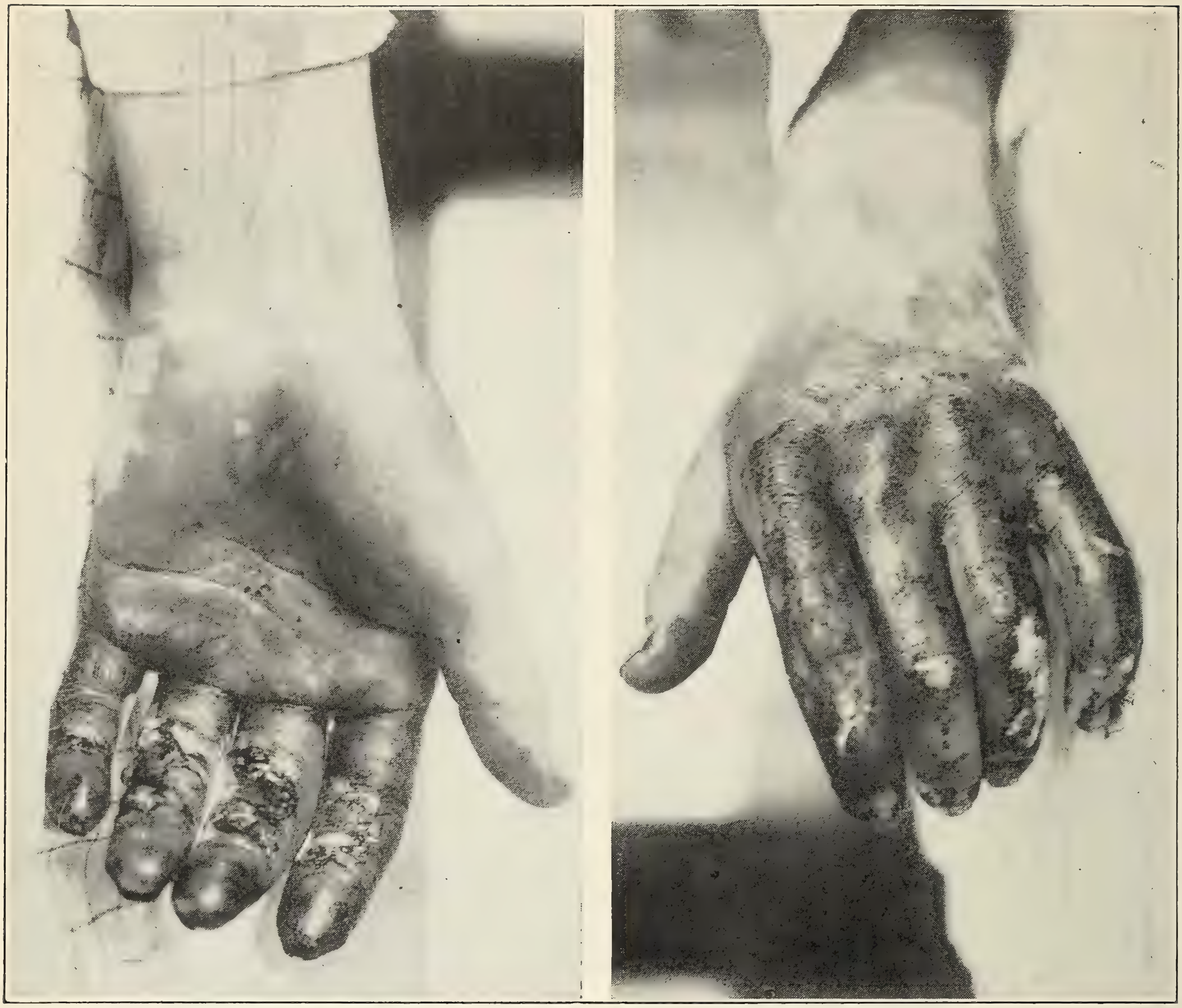

FIGURE 32. (*a* and *b*). This case illustrates the proper treatment for a lacerated wound over the front of the fingers exposing the flexor tendons. This patient's hand was caught in a dough mixing machine. The trauma was of the tearing and compressing type. Extensive irregularly shaped lacerated wounds were found over the front of the index, middle and ring fingers, exposing the flexor tendons. After careful skin preparation, the wounds were completely debrided and sutured so as to cover the exposed tendons and, at the same time, avoiding undue tension. Active motion was instituted immediately. The photographs were taken on the 6th postoperative day, and indicate the amount of active flexion on that date.

and a bad flexion contracture. I feel convinced that this could have been avoided had more conservative treatment been followed.

Any extensive laceration calls for an immediate operation which consists of a thorough cleansing and a complete debridement. (See Figure 30.) Very frequently, one sees lacerated wounds over the front of the fingers which have been produced by a crushing force. They are usually irregularly shaped and often extend down into the tendon sheath, exposing the flexor tendons. The great danger in these cases is the development of a tendon sheath infection. I feel that the incidence of this complication may be reduced to a minimum by careful cleansing of the wound and the surrounding skin and a painstaking excision of the edges of the laceration. As many sutures should be inserted as is necessary to cover over the exposed tendons. Their number should be the minimum so as to avoid undue tension. I believe that tension of tissues is a great factor in the development of infections following the operation of debridement and suture for compound injuries. Figure 32 indicates a case with extensive lacerations over the front of three fingers treated according to this method. The flexor tendons of each finger were exposed by the injury. The photographs were taken on the sixth postoperative day and indicate the amount of flexion at that date.

THE NERVES OF THE HAND

(See Figure 33.)

Proper hand function is dependent upon adequate sensation and finger mobility. Complete sensation is directly bound up with nerve integrity and motion is dependent upon both muscle and tendon function as well as complete nerve distribution. The one is as important as the other. The degree of disability that a divided nerve entails depends upon which nerve is involved and at what level the point of division has occurred. Thus, severence of the median nerve at or above the wrist produces anæthesia in the three digits most often used. In addition to skin anæsthesia, joint sense is disturbed. Trophic changes appear and the patient often burns the involved fingers without knowing it. There is also a loss of the power of opposition of the thumb to the fingers. Severence of the ulnar nerve at or above the wrist produces anæsthesia in the area supplied by this nerve and results in a claw-hand, with deficient thumb function and loss of the fine movements of the fingers. From the standpoint of hand function, then, it will be seen that the two most important nerves in the hand proper are the thenar motor branch of the median, already alluded to, and the motor branch of the ulnar. The

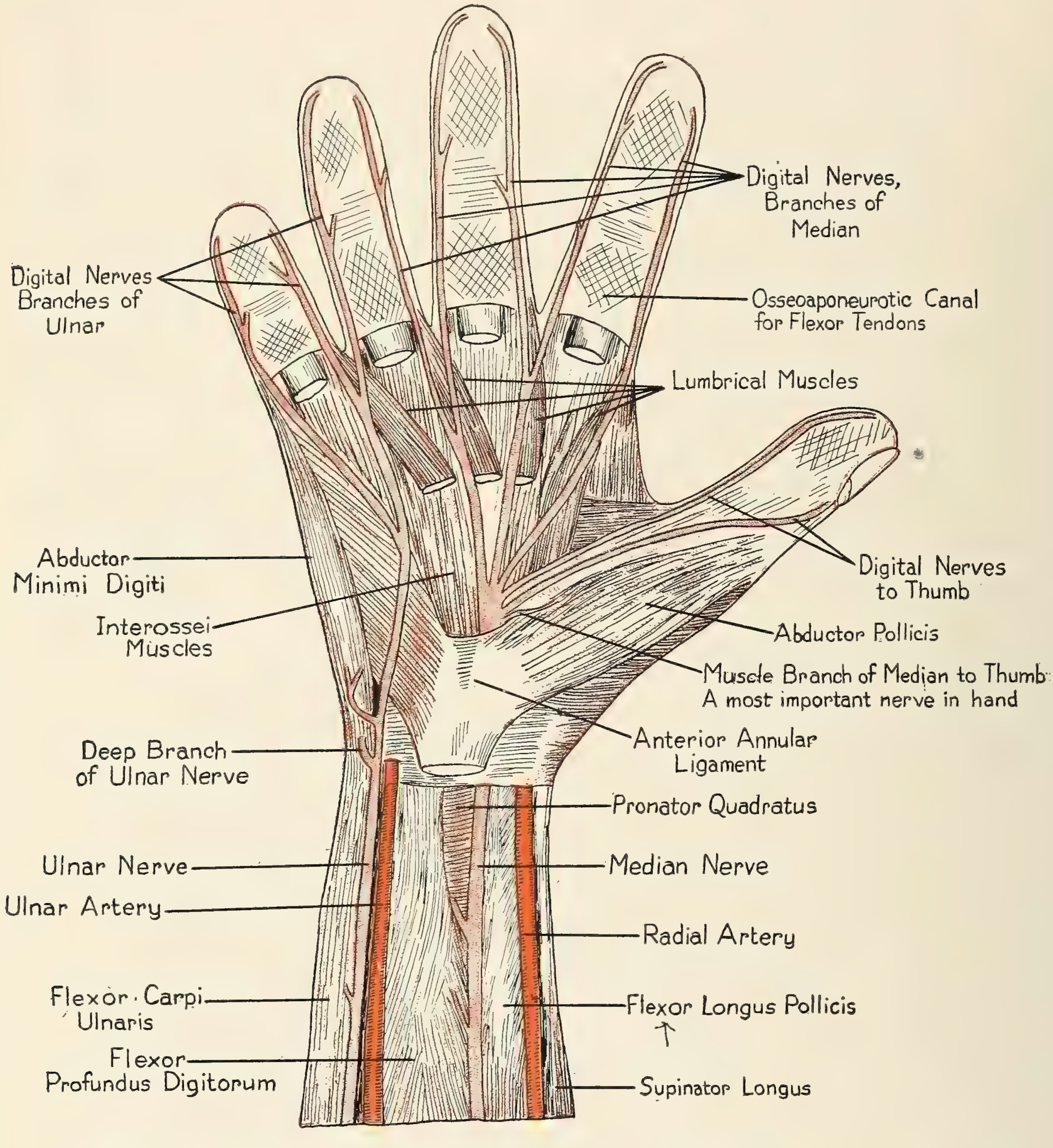
Digital Nerves, Branches of Median
Digital Nerves Branches of Ulnar
Osseoaponeurotic Canal for Flexor Tendons
Lumbrical Muscles
Digital Nerves to Thumb
Abductor Minimi Digiti
Interossei Muscles
Abductor Pollicis
Muscle Branch of Median to Thumb: A most important nerve in hand
Deep Branch of Ulnar Nerve
Anterior Annular Ligament
Pronator Quadratus
Ulnar Nerve
Median Nerve
Ulnar Artery
Radial Artery
Flexor Carpi Ulnaris
Flexor Longus Pollicis
Flexor Profundus Digitorum
Supinator Longus

FIGURE 33. Drawing of a dissected hand illustrating the important nerves of the hand. The ulnar nerve passes in front of the annular ligament and gives off its deep branch which follows the course of the deep palmar arch. The median nerve passes beneath the annular ligament. Its first branch in the hand is an important one, the thenar motor branch to the thumb. The digital nerves lie just beneath the digitations of the palmar fascia with which they may be easily confused. Their importance to hand function and efficiency cannot be over-emphasized. Repair of divided digital nerves by the technique described in the text gives excellent results.

remaining branches of these two nerves are sensory in function, but are just as important.

To determine the presence or absence of nerve injury, it is imperative that skin sensation distal to the injury be tested in every instance. This applies just as much to finger injuries with severence of the digital nerves as to wounds in the palm and at the wrist where the main nerves may be involved. Once the loss of skin sensation is evident on physical examination, the repair of the divided nerve is indicated. This should be done at the same time that the laceration or divided tendon is repaired.

The repair of nerves in the hand, while not a simple operation, is not difficult. The results in my hands have been fairly uniformly satisfactory. The few rather unsatisfactory end results that I have had have been in cases of severence of the ulnar nerve at or above the wrist. The reason for this is not clear but I believe it has also been the experience of many other surgeons. The end results following suture of the divided digital nerves have been unusually brilliant. (See Figure 28.) This is probably because these nerves are purely sensory and do not contain mixed fibres. Bunnell, of San Francisco, in a recent admirable article was the first to report a series of such cases with practically uniformly successful results. His findings indicate that the period of regeneration is shorter the nearer one approaches the tip of the finger, and is longer in cases where the injury is more proximally located. In his series, the average period of regeneration of a divided median or ulnar nerve at the wrist was thirteen months. Where the divided nerve was situated at about the middle phalanx, the average period for regeneration was one and a half months.

In the actual repair of a divided nerve, the same atraumatic technique as already described should be followed. To approximate the divided ends, the finest silk obtainable should be used. I have made use of the thin needles and silk sold on the market for suturing blood vessels. Five or six sutures are placed in the perienural tissues in such a way that, when the knots are tied, there will be an accurate approximation of the ends of the divided nerve. Under no circumstances should the suture material enter the substance of the nerve. To permit repair, the involved parts should be put in the position of relaxation with flexion of the various joints. Depending upon which nerve has been repaired, this position of flexion ought to be maintained for a period of three to five weeks. Electrical stimulation of the muscles supplied by the divided nerve is an important factor in postoperative therapeusis.

RECONSTRUCTION SURGERY OF THE HAND

This field of hand surgery is both an important and difficult one. The hands that come for reconstruction work are usually among manual workers, so that their proper function is of vital importance to the patient. It is a difficult subject because of the innumerable problems that arise which must be solved. From the economic standpoint, a great advance will be made when the numerous insurance companies and state industrial boards become educated to the fact that a great deal can be done for the majority of the cases which they discard as hopeless. In New York State, at least, the attitude of the industrial commission is such that insurance companies will not undertake the cost of any reconstruction work, especially when it entails additional scars and the removal of anatomically unnecessary tissues from other parts of the body which might be used in the repair of a hand. This has been the writer's experience again and again, and it constitutes a deplorable state of affairs. The examining physicians at the industrial commission make awards for scars, etc., of such extent that, even though the worker has obtained an excellent functional result, the cost to the insurance company is so prohibitive that they will not undertake similar experiments in subsequent cases. To overcome this improper attitude will require considerable education and propaganda among the laity, the industrial boards, and the profession.

It is beyond the scope of this article to minutely describe the innumerable details that arise in a consideration of this extensive subject. Only basic principles and their application to the various problems will be considered.

The hands that one sees range from those that require but a simple repair of a divided tendon or nerve, to those with extensive crippling, in which many or all of the structures have been injured. A previous infection may leave a replacement fibrosis with firm cicatricial tissue which congeals the various structures together. Loss of skin may leave various deformities with impairment of function. The joints may be stiffened in poorly functionating positions. Varying lengths of tendons and nerves may have sloughed and been replaced by scar tissue. It will be seen then, that the problems in hand reconstruction involve repair of all the tissues. In each individual case it is necessary to obtain a careful history of the preceding incidents, a painstaking examination of the hand from the standpoint of skin contracture, nerve injury, tendon function, and joint mobility, and photographs before an operation is performed, and during each stage of the subsequent treatment until the final result. The latter may not be obtained before the expiration of a year or more. It is one type of surgery which can not be hurried.

Before any work can be done on the subjacent structures, it is necessary to replace the overlying skin and subcutaneous tissues, should examination disclose extensive cicatrization of these structures. This is accomplished by the use of a pedicle skin flap from the abdomen or chest in the form of a tubular flap. (See Figure 34.) After determining what the most comfortable position for the patient will be during the process of

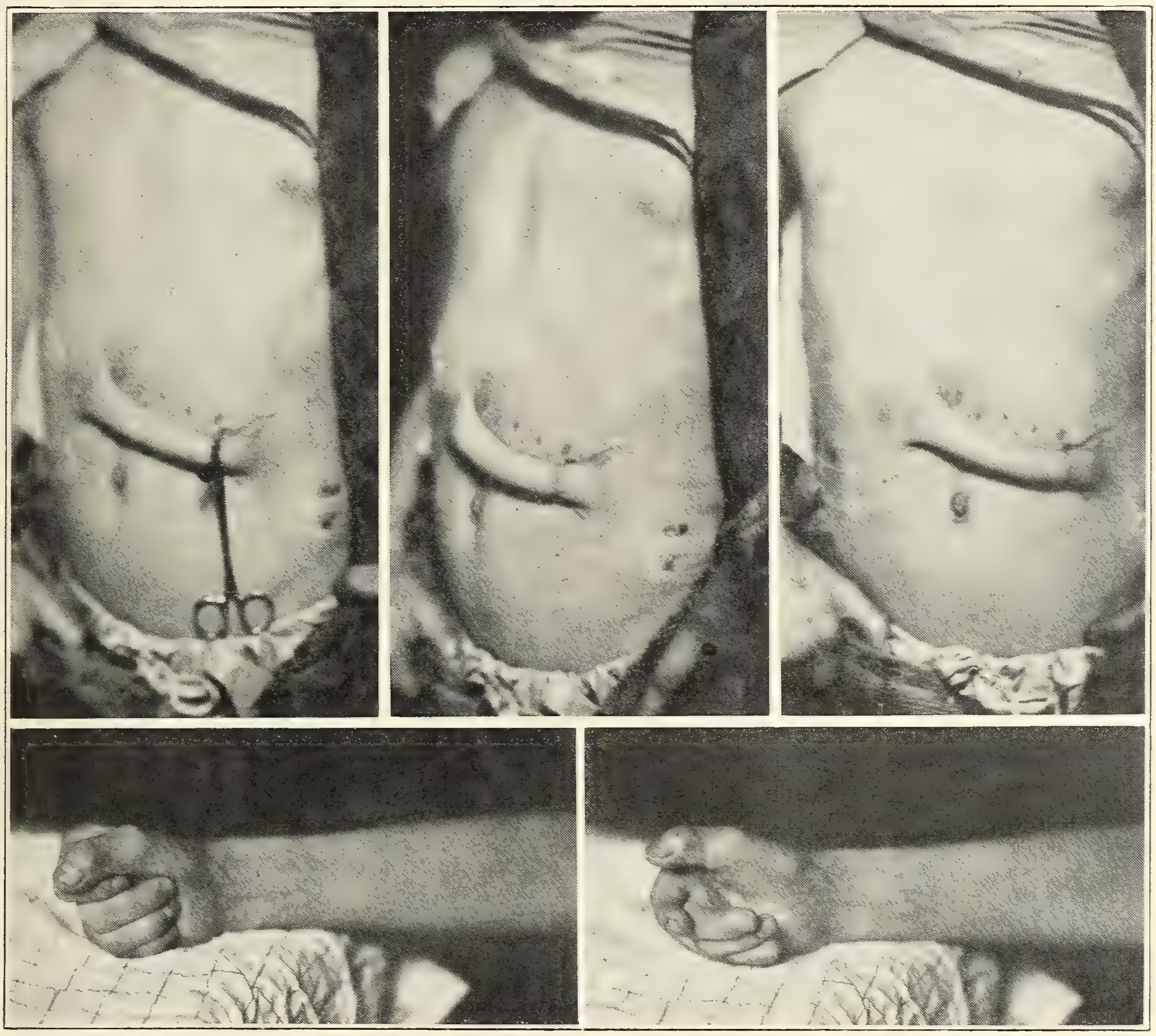

Figure 34. (*a*, *b*, *c*, *d* and *e*). This case illustrates one problem in hand reconstruction. The flexion contracture of the palm is due entirely to scar replacement of the skin and subcutaneous tissues. The tendons are intact. The nerves are uninjured. The problem here involved complete excision of scar tissue and the application of a pedicle skin flap from the abdomen. The photographs indicate the tube flap prepared on the abdomen and the method used for compression of one pedicle. The exact details may be found in the text.

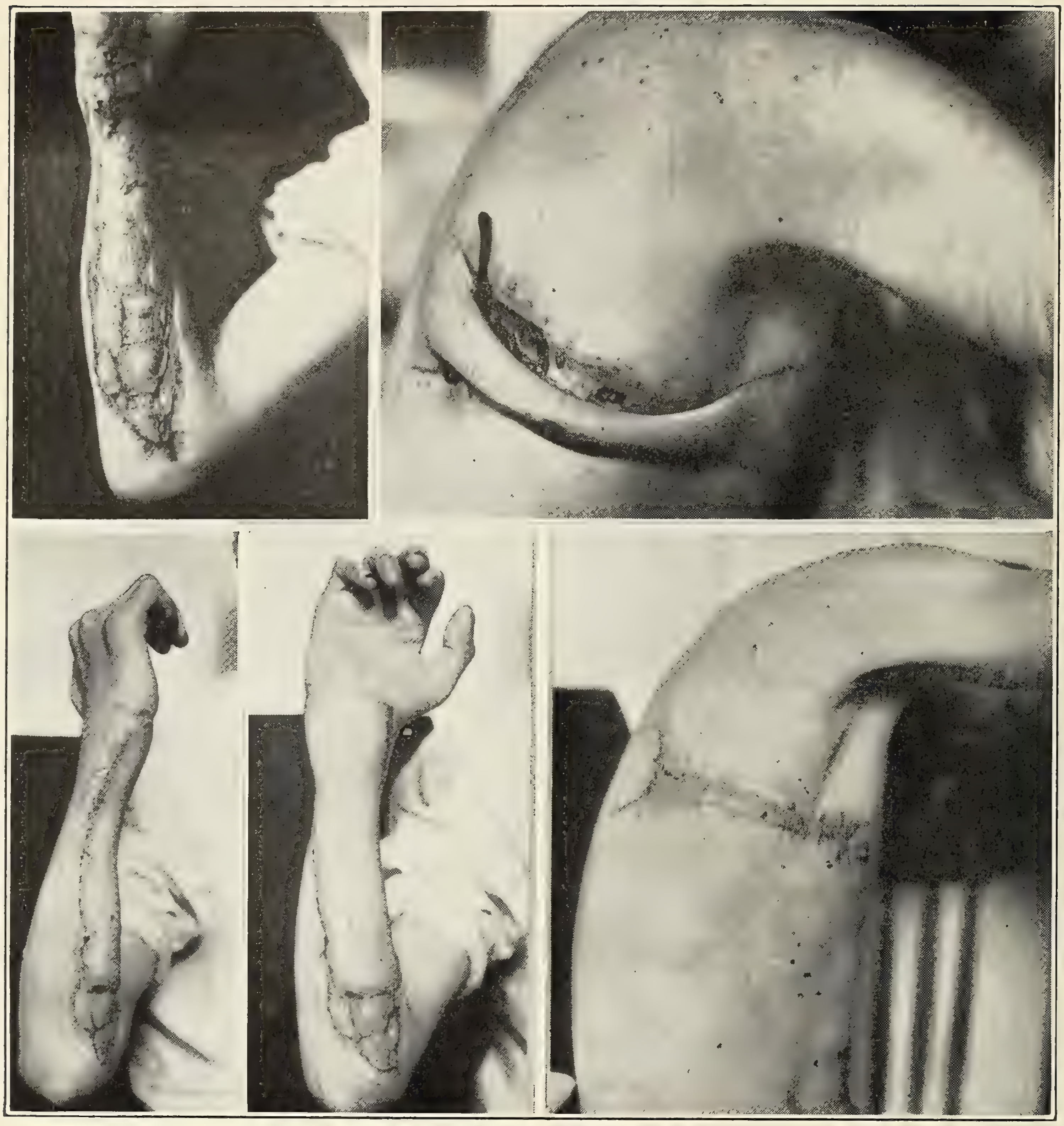

FIGURE 35. (*a*, *b*, *c*, *d* and *e*). This case illustrates many problems in forearm reconstruction, but is used here to indicate the size of a skin flap taken from the side of the chest. This patient, as a result of an ammonia explosion, lost all the flexor tendons and median and ulnar nerves. The resulting granulating wound was covered with Thiersch grafts to minimize scar tissue formation. At a later date a pedicle skin flap from the side of the chest was applied to the forearm after complete excision of the forearm scar. Photographs indicate the size of the flap, the method of rubber band compression, and the finished product on the forearm, as well as the resultant scar on the chest wall.

union of the skin flap to the hand, an area is marked out on the abdomen or chest, somewhat larger than the expected deficiency in the hand after excision of the cicatrix. This flap is left attached at its upper and lower pedicles, but is lifted from the underlying fascia throughout the remainder of its length. The remaining skin edges, after the flap has been lifted, are undermined and approximated beneath the flap with silk worm gut sutures. These sutures should be left intact for a period of eight to ten days, to prevent spreading of the scar. The flap which has been raised, is rolled into a tube, so that only skin surfaces are exposed, and the opposing skin edges of the flap are sutured with interrupted fine horse-hair stitches. Hemostasis must be complete to prevent the formation of hematomata and to diminish fibrosis in the flap. I have been using this type of skin flap almost exclusively because one is sure of the blood supply and, by eliminating all raw areas, asepsis is maintained. This constitutes the first stage operation. After about two weeks, gradual compression of one of the pedicles is instituted. I have been in the habit of using rubber band compression with gradual daily increasing periods of occlusion of the blood supply. (See Figures 34, 35, 39.) Another method recommended, consists in a gradual cutting through of one pedicle. The objection to this method, however, is that a raw area is produced, thus bringing in the much-to-be-avoided contamination.

When rubber band compression for a period of twenty-four hours results in no disturbance of circulation, the second stage operation may be performed. This consists in the careful and thorough excision of all cicatrizing and subjacent scar tissue in that part of the hand which is being subjected to reconstruction. Existing deformities which may have been produced by the scar, are corrected. For instance, a flexion contracture of a finger is immediately overcome as a rule, when the contracting scar is excised. (See Figure 39.) The now extended finger is then placed upon a sterile metal splint which had been previously cut out to fit the part. The skin flap on the abdomen is then divided through the pedicle which had been undergoing daily compression. The suture line on the back of the tubed flap is opened, thus allowing the flap to become now a flat piece of skin and subcutaneous tissues. Excess fat should be removed to prevent an unsightly appearance in the hand. The hand is then brought across the front of the abdomen or chest and the flap is sutured to the deficiency created by the excision of the scar tissue, using horse-hair or fine silk worm gut. The fit should be exact. Before the application of the flap to the hand, hemostasis must be complete and dead spaces must be avoided. Dressings are then applied and firm even pressure placed upon the flap by an encircling sterile bandage. Great care must be exerted to prevent any impairment of circulation in the remaining pedicle of the flap by kinking, bandage pressure, or any other avoidable cause. To favor union of the flap to the hand, absolute immobilization is essential, and this can be obtained only by the use of a plaster shoulder spica which maintains the arm efficiently by the side and is also comfortable for the patient.

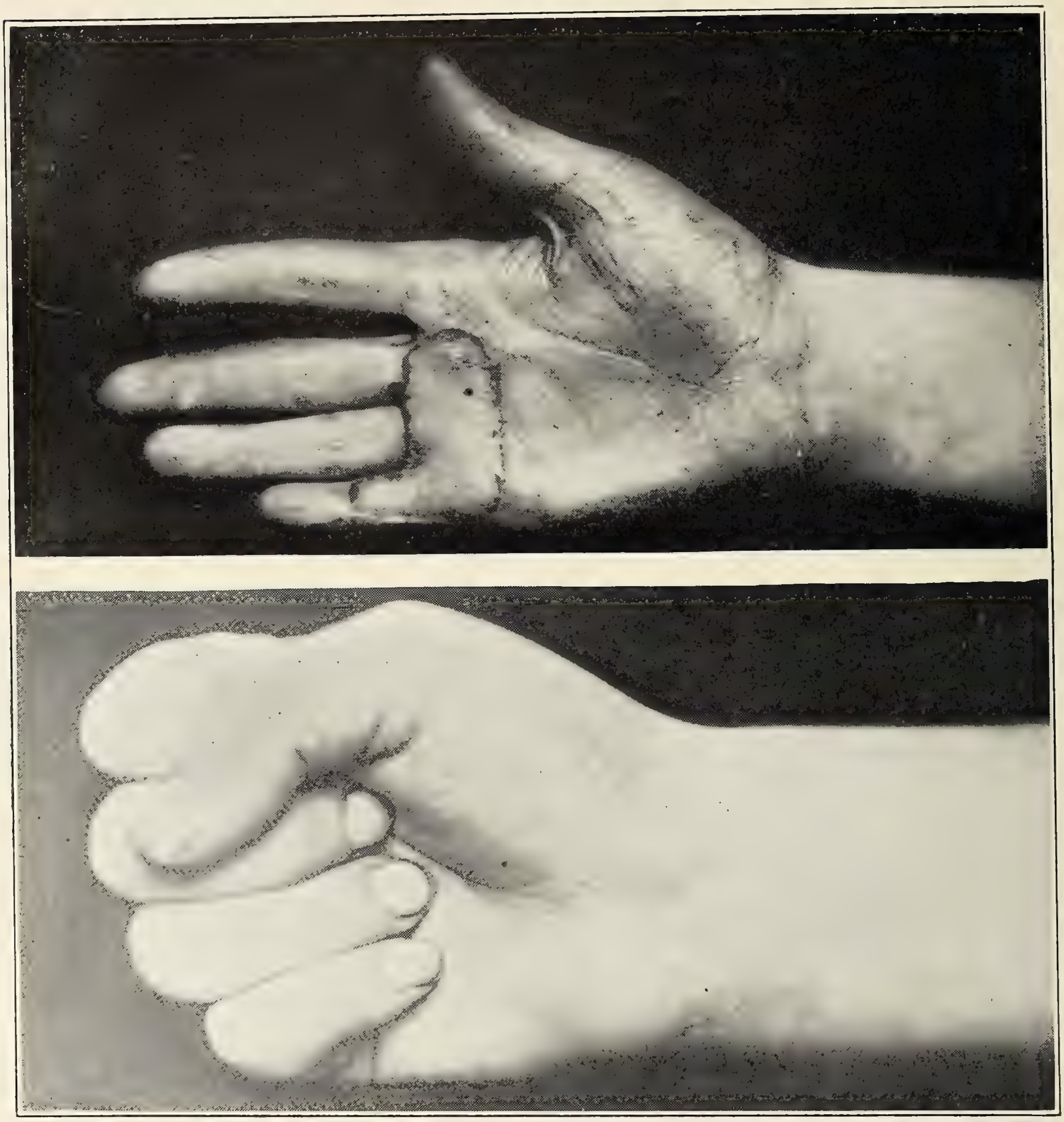

FIGURE 36. (*a* and *b*). This case illustrates the end result of the application of a pedicle skin flap for a flexion contracture of the little and ring fingers, following a burn. This was done in 3 stages, as described in the text. There was no involvement of the tendons, nerves, or joints. The pathology was confined to the skin and subcutaneous tissues.

After a period of two to three weeks, the remaining pedicle may be divided as a third stage procedure, and the remainder of the flap sutured to whatever deficiency may exist in the hand. The use of such a flap provides a soft fatty bed in which reconstructed tendons may be placed, and also, by relaxing all of the tissues which had been held by scar tissue improves the nutrition of the whole hand. During the two or three month period, subsequent to the application of the flap, the patient should be warned against the possibility of burning or injuring this new skin. At the end of about three to six months, depending upon the size of the flap, complete regeneration of the skin nerves will have taken place.

Before any work can be done upon the tendons, stiffened joints must be mobilized. This may be accomplished by gradual stretching of the thickened joint capsules through the use of any splint or appliance which applies to the joint mild and continuous traction over a period of time necessary for complete mobilization. Force is contra-indicated. Great harm is done when attempts are made to forcibly mobilize stiffened joints under an anæsthetic. It will be found in the majority of these hands that stiffened joints assume non-functionating positions. The wrist joint will be found flexed and the metacarpo-phalangeal joints extended, and the thumb abducted. The wrist should be put up in a cock-up position, the thumb drawn into opposition toward the palm, and the metacarpo-phalangeal joints placed in flexion. The latter very often will be found difficult to accomplish. Any device which places padded pressure over the heads of the metacarpal bones in the palm and the dorsal surfaces of the proximal phalanges near their distal ends, thus producing pulling force in opposite directions, will cause gradual stretching of the posterior capsules of the metacarpo-phalangeal joints. In cases that resist this form of treatment, a posterior capsulotomy hastens mobilization. The application of similar principles may be used in the intelligent mobilization of other joints in the hand. Impairment of pronation and supination due to an ankylosis of the inferior radio-ulnar joint may be completely relieved by removal of the distal end of the ulna. During this period of mobilization, use should be made of every physio-therapeutic aid at the command of the surgeon to maintain whatever gain has been achieved.

Great impetus has been given by Bunnell of San Francisco, to the problems of reconstruction surgery of the flexor tendons of the hand. His experience in this direction has been extensive and his published results have been unusually satisfactory. A clear conception of the histological anatomy of the various tendon structures of the body is necessary before one can expect to obtain satisfactory results in this type of surgery. This entire problem has been carefully worked out by Mayer and Biesalski who emphasized so well the importance of the gliding mechanism of a tendon. Briefly, their findings are as follows: When a tendon pulls in a straight line, it is encircled by loose fatty tissue of great elasticity called *paratenon,* which is pulled back and forth in its central zone with movements of the tendon. When a tendon pulls around a corner, it is enclosed in a tendon sheath, in which the surface of the tendon (*epitenon*) moves freely in the synovial lining of the sheath. This is found in the hand. In other parts of the body, a blood-vessel-bearing *mesotenon* is present, being attached to the epitenon opposite the side of friction. In the hand, the mesotenon is represented by the attenuated structures, the vincula tendineæ. With this picture of the encircling tendon anatomy clearly defined, the indication in all reconstructive tendon work in the hand is to maintain the old or supply a new gliding mechanism. In the vast majority of cases, the latter will be found necessary.

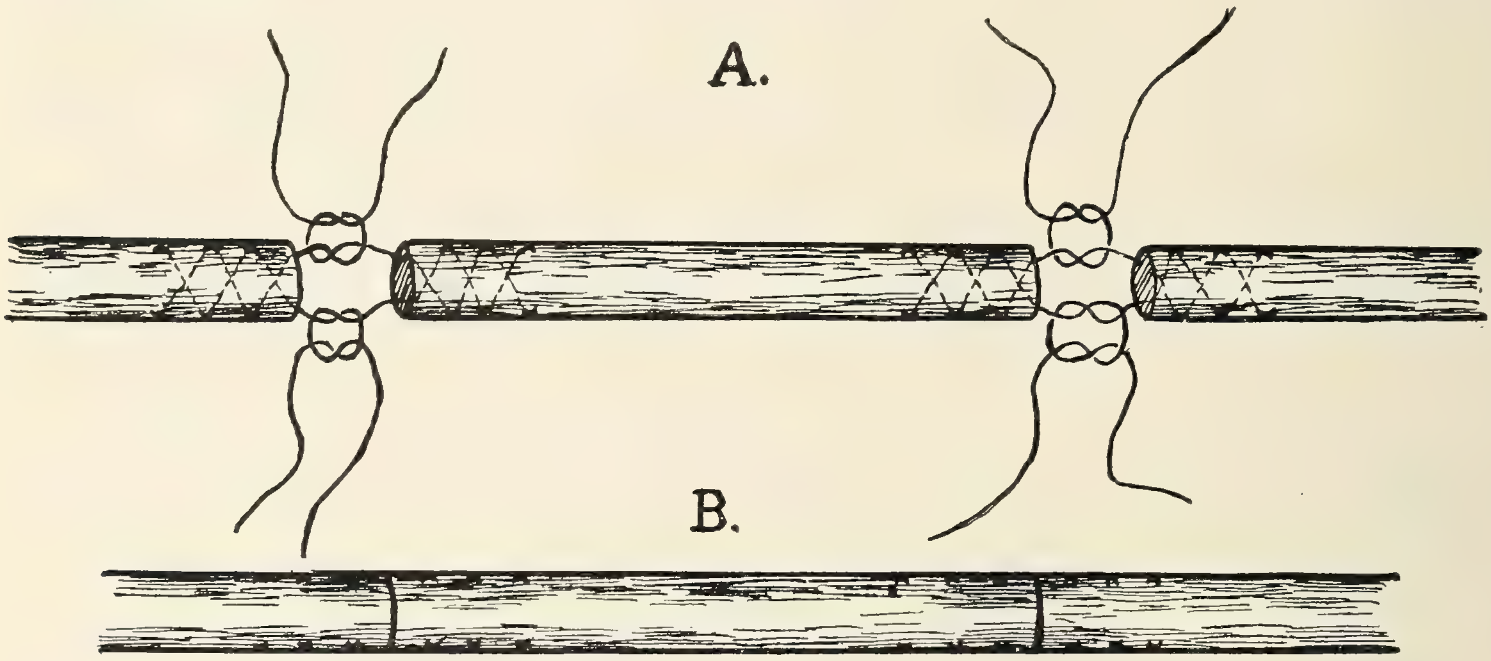

FIGURE 37. Method recommended for the insertion of a tendon graft to fill a defect in a hand tendon. It will be seen that the same suture method is used as described in the legend under Figure 23, with the exception that the suture material is braided in each end of the tendon graft, as well as the stumps of the tendon being repaired. After the various suture ends are tied, it will be seen that the knots lie completely buried with a minimum amount of suture material on the surface of the tendon.

From experience, it has been found that it is impractical to graft a tendon with its tendon sheath. Therefor, the nearest approach to the normal gliding mechanism in the hand is the substitution of the paratenon type of gliding mechanism. The tendon of the palmaris longus muscle with its surrounding paratenon fat is the best structure for this use. The long extensor tendons of the toes may also be used, the loss of their function being taken up by the brevis tendons. Paratenon fat is found over the triceps tendon and fascia lata. If the tissues in a finger are practically free from cicatrix, it may be advisable to use as a graft the sublimis tendon of the same finger. If, however, there is considerable scar tissue, a graft with more paratenon fat about it should be used.

Free tendon grafts should be inserted rather than to attempt resuture of the two ends of the old tendon, because it will be found that the muscle belly has contracted to such an extent that the ends of the tendon can not be approximated with normal tension. (See Figure 37.) Where there has been sloughing of tendon due to infection, the insertion of tendon grafts becomes necessary. When it is necessary to replace a tendon in the finger proper, a long graft should be used so that its points of suture will be in the palm and at the distal phalanx. (See Figure 39.) If one attempts to suture a graft in the finger so that the suture line will be within the narrow confines of the tendon sheath, one is apt to have denser adhesions than by the method just described. It is not necessary to duplicate the condition found in a normal finger, i. e., both the flexor profundus and sublimis tendons. One flexor tendon in a finger will suffice, providing the vaginal ligaments, already alluded to, are intact. It is important to realize the significance of the vaginal ligaments in a consideration of tendon grafts in the finger. Their absence causes a bowstringing of the tendon forward, thus interfering with the tendon's mechanical efficiency. If it is seen that these vaginal ligaments or pulleys have been destroyed, they may be reconstructed by making a loop of

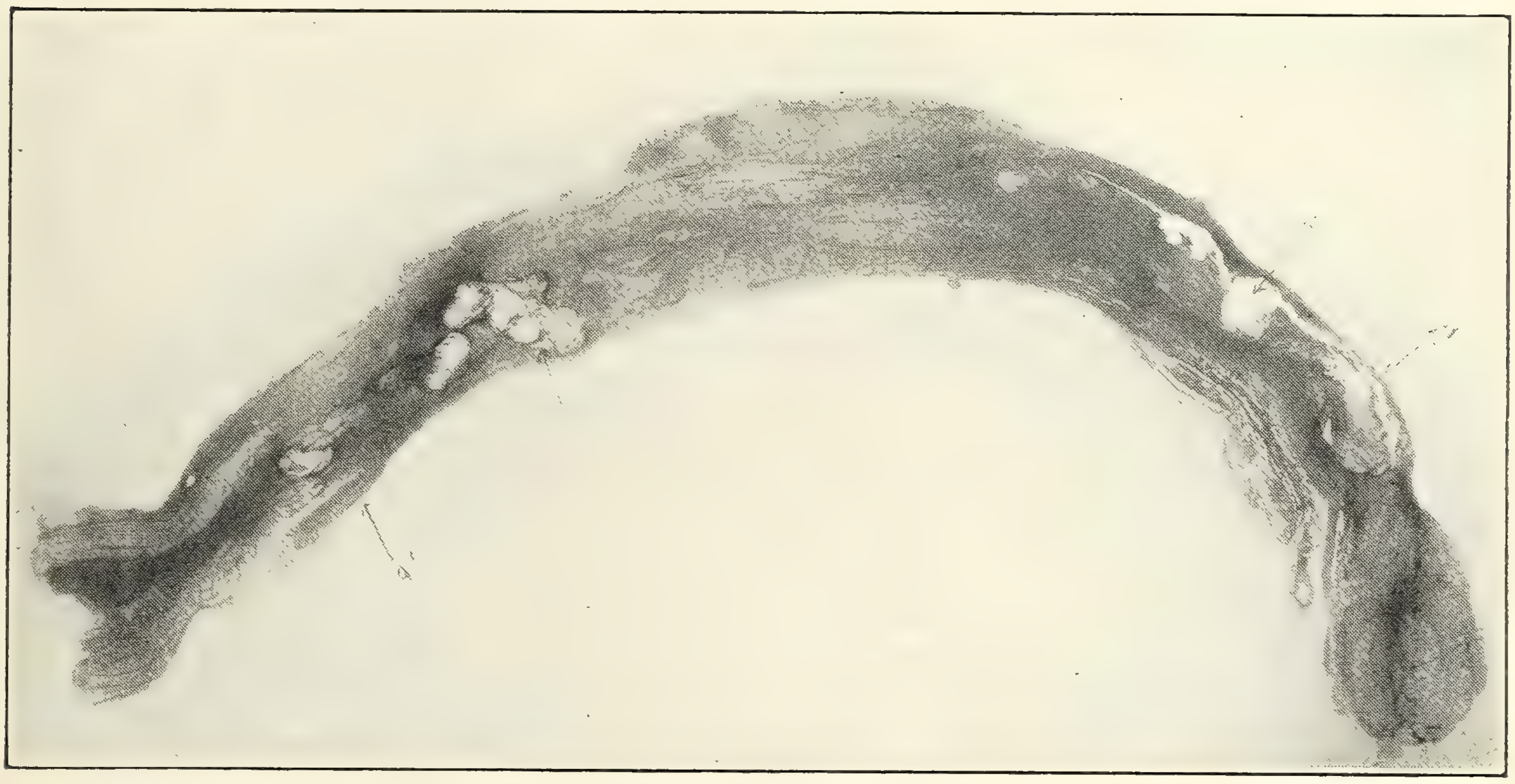

FIGURE 38. Photomicrograph of a specimen excised from a dog's tendon. A free tendon graft was inserted to bridge a defect made artificially in one of the anterior tibial tendons. The technique indicated in Figure 37 was used. Motion was started on the 9th postoperative day, and the wound reopened on the 16th day. Grossly, the graft was found to be firmly united, but with light adhesions between it and the sheath. The specimen shows the suture material in the graft itself, at *A*, and in the proximal and distal ends, at *A* prime. The firm union between these points and the viability of the cellular structures of the graft is to be particularly noted. The lack of adhesions is noteworthy.

free tendon graft, and suturing its ends together posteriorly so that it encircles both the bone and flexor tendon. (See Figure 39.) This must be done in the region of the middle and proximal phalanges, and the head of the metacarpal bone.

Very often it becomes necessary to insert multiple tendon grafts. If they extend from the region of the distal forearm, they will lie close together at the wrist and beneath the annular ligament. The tendency for their surfaces to become glued together by adhesions in this region is great, and additional means must be used to obviate such an event. In addition to the paratenon fat already present on the surfaces of the grafted tendons, use may be made of a large graft of paratenon fat taken from the triceps region which is interposed between the various newly inserted tendons. This will tend to increase the efficiency of the gliding mechanism. Not infrequently, after the insertion of a tendon graft, adhesions will form which will bind the new tendon in its bed and prevent function. A second operation may be necessary to free the tendon from its encircling adhesions. At this operation, use may be made of a special instrument devised by Bunnell, called a tendon stripper. After operation, active motion is instituted immediately to prevent the reformation of adhesions. In all tendon grafting, the principle, as determined by Mayer, of the proper tension for uniting a tendon must be followed. When the origin and insertion of a muscle are approximated as close together as possible, the tension of the tendon should be zero, the only exception being in the case of a muscle, which, owing to division of its tendon, has long been contracted.

The operative technique in this type of surgery must be an exacting one. The atraumatic technique already alluded to is particularly applicable to this work. The incisions used ought to be remote from the point of tendon suture or graft, should not cross flexion creases at right angles, and should, as a rule, parallel the creases of the hand. The L-shaped incision already described seems particularly applicable here. A bloodless field is a sine-qua-non.

In 1927, the writer reported the results of some experimental work done to clarify numerous points in tendon surgery. The main inquiry in the study of repair processes involved in free tendon grafts centered about the question as to whether the grafts live as such, or form a bridge, as in bone grafts, along which cells grow from the proximal and distal ends of the repaired tendon. The experiments seem to show definitely that a graft lives as such, and that the repair proceeds along the same lines as in an ordinary simple tenorrhaphy. It is probable that the graft derives considerable nutrition from the tissue juices in the initial few days. The

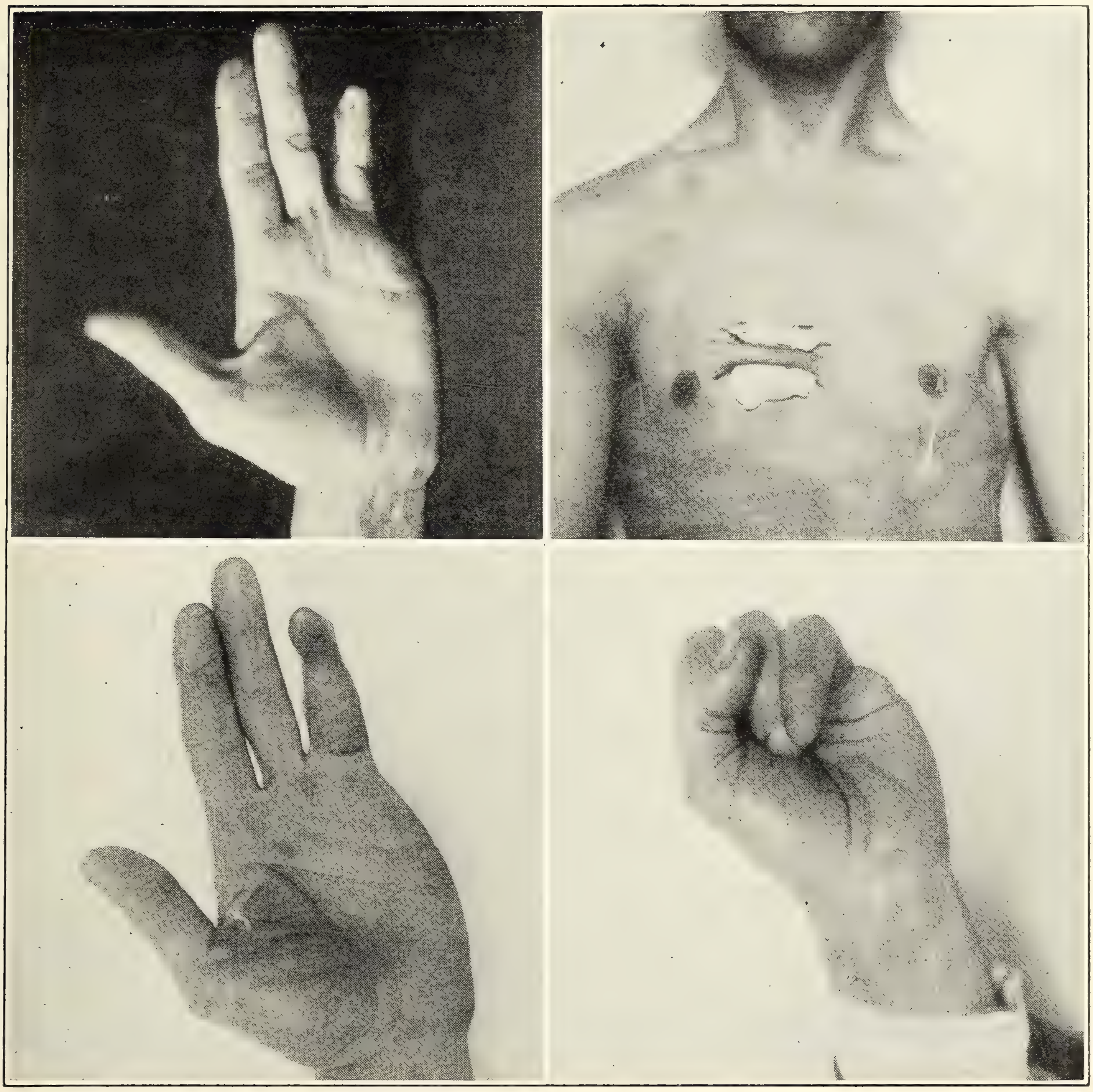

FIGURE 39. (*a*, *b*, *c* and *d*.) This case illustrates another problem in hand reconstruction. This patient received an injury to the hand resulting in amputation of the little finger, and an extensive crushing laceration over the front of the ring finger with loss of both flexor tendons. A flexion contracture developed. The problem in this case was threefold:

1. The replacement of the scar tissue over the front of the finger by normal skin and subcutaneous tissues.
2. Mobilization of the joints.
3. The insertion of a tendon graft.

The first was handled by the use of a tubularized pedicle graft from the front of the chest. Eleven days after the preparation of the flap, it was sutured to the front of the finger by the technique described in the text. At a later date, the various joints were mobilized by a specially constructed splint. As a final stage, a free graft of the palmaris longus tendon was inserted, its points of suture being in the palm and at the base of the distal phalanx. The vaginal ligaments of the tendon sheath which had been destroyed at the time of injury, were reconstructed by the use of free grafts taken from the remains of the flexor sublimis tendon of the same finger. The photographs indicate the result obtained.

main source of nutrition, however, seems to be derived from the young capillaries and lymph vessels from the tendon ends and from the subendothelial tissues of the sheath. (See Figure 38.) Another point which this study clarified, involved the optimum period for beginning motion. It was found that active motion can safely be instituted on about the tenth or twelfth postoperative day, and that union of the graft was firm on about the twenty-fifth day. This finding is of significance in the postoperative treatment.

The opposing action of the thumb is its most important function. The completeness of this function depends upon the integrity of the abductor opponens and pollicis muscles and the thenar motor branch of the median nerve. The loss of this function may be caused by injury to the thenar motor branch, injury to the median nerve above the wrist, and destruction of the two muscles mentioned above. Examination of the case will indicate which of the three possibilities is the producing cause, and treatment is carried out accordingly. If suture of the thenar motor branch is impractical or the two thenar muscles have been destroyed by disease or injury, then use may be made of any of the tendon transplantation operations recommended for this condition. Bunnell uses a very ingenious method which consists in running one of the flexor tendons of the forearm through a pulley at the pisiform bone, and then running the tendon or its prolongation by a free tendon graft subcutaneously to the dorsum of the distal end of the metacarpal of the thumb, and then passing it through a drill hole and suturing. The pulley is a loop of tendon graft looped about the origin of the abductor minimi digiti. He recommends the use of the flexor carpi ulnaris muscle. From a mechanical standpoint this operation should give excellent opposition of the thumb.

In considering reconstruction work of the hand, careful attention must be paid to the presence or absence of nerve injury. Experience seems to show that repair work of the tendons results in a speedier convalescence and better end results, when the nerve injuries are attended to first. Unless infection and injury has resulted in the loss of large sections of a nerve, end to end suture may usually be performed by freeing both ends of the nerve as far as possible. More length may be attained by flexing the fingers, the wrist, the elbow, and even the shoulder. In repair of an ulnar nerve, length may be gained by transplanting it to the front of the elbow. Where great gaps exist between nerve ends, use may be made of cable nerve grafts taken from the long sural nerve of the leg. The operation of nerve grafting is technically very difficult. Stookey emphasizes the fact that the grafts should lie in practically normal tissues. Placing nerve grafts in a bed of scar tissue will result in their early strangulation.

Nerve grafting, judging from the experience of surgeons who have reported their results, should only be done as a last resort.

A word of warning is here in order. Reconstruction work of a disabled hand must never be undertaken lightly. The operations are unusually difficult and disappointments are frequent. One must evolve for himself an operative technique which is always cognizant of possible microscopic tissue injury. Only after an experience involving many cases, may one begin to expect satisfactory functional results. It is a field of surgery which has many pitfalls and unexpected disappointments. The tissues of different patients react in different ways, and one is unable to foretell how one particular patient's tissues will respond to a particular operative procedure. The whole subject may be summed up as follows: Great care is to be exercised in the proper selection of cases. The surgeon must never be hurried into obtaining his final result. A year or more may be necessary before this can be obtained. The operative technique should be of the atraumatic variety. The great importance of postoperative care has to be emphasized. Due consideration should be given to the repair of skin, subcutaneous tissues, nerves and joints, as well as tendons. Above all, the patient should be cognizant of the fact that the result may not be up to his expectations.

DUPUYTREN'S CONTRACTION OF THE PALMAR FASCIA

A not infrequent condition encountered in the hand is the lesion first described by Dupuytren in 1831, and now called by his name. The pathology primarily is located in the palmar fascia and its digitations in the fingers. The overlying skin is secondarily involved.

The lesion occurs in adult life, being most common between the ages of thirty and fifty. It is more frequently seen in men than in women, and one or both hands may be affected. More often, bilateral involvement is present. In my experience, the ring and little fingers are more frequently involved than the others I have never seen a case nor heard of one with the disease in the index finger or thumb.

The actual cause of this disease in unknown. A number of observers have felt that local trauma is the main predisposing cause. The fact that the majority of cases are found in manual workers would seem to bear out this contention. The most recent thought relative to the etiology attaches considerable importance to focal infection plus the long continued trauma. The latter produces a *locus minoris resistentiæ* where circulating organisms may lodge and produce a low-grade inflammation. Actual experimental or other evidence to corroborate this view-point has not been forthcoming.

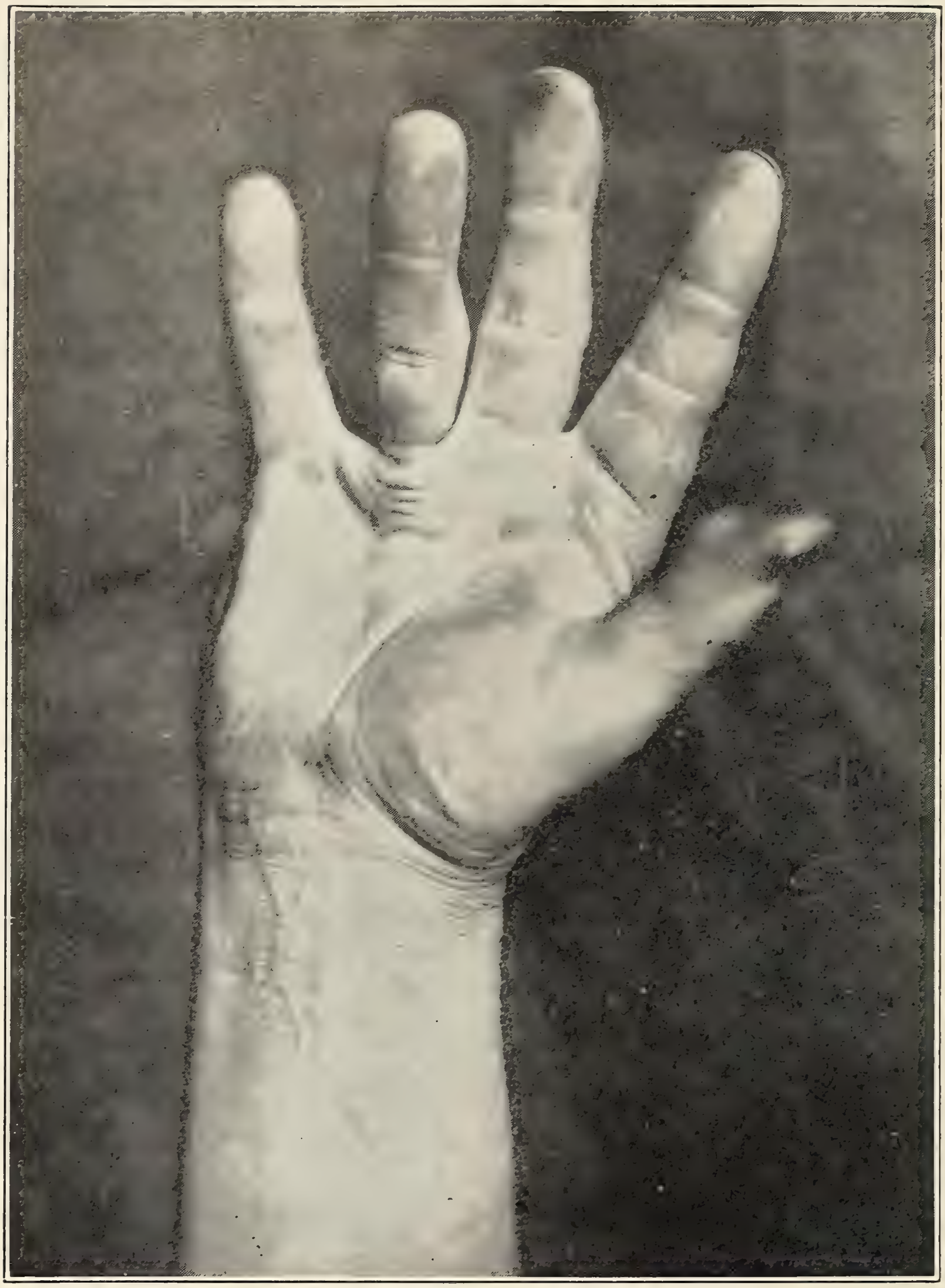

Figure 40. This photograph shows a typical Dupuytren's contraction of the palmar fascia. The nodular appearance of the skin immediately overlying the involved fascia, is clearly shown, as is also the band of fascia running from the palm into the finger. The most marked involvement in this case exists in the ring finger. The little finger is also slightly involved.

The onset of this condition is very gradual and without pain. It commences as a nodular thickening of the palmar fascia at about the level of the distal palmar flexion crease. The overlying skin soon becomes attached to the fascia and presents a thickened, contracted and puckered appearance. The involvement extends later to the digital prolongations of the palmar fascia into the lateral and central aspects of the finger. This produces a progressive gradual flexion of the finger toward the palm. If the disease is allowed to progress far enough, this flexion contracture may become so marked as to render the hand useless. (See Figure 40.)

Treatment. Although a number of operations have been advised for the cure of Dupuytren's contraction, none should be considered in the treatment of this condition unless it involves the complete excision of the diseased fascia. The operations described by Dupuytren, Adams, Kocher, Keetley, and others, are totally ineffective in producing a cure because the essential step in each consists in a division of the contracting fascial bands rather than an excision. I believe that the Adams operation is a particularly dangerous one because the digital nerves are very apt to be divided. In this operation, a fine tenotome is inserted between the skin and the fascial bands which are divided subcutaneously after the manner of a tenotomy of the Tendo Achilles. In all of the operations mentioned above, the danger of dividing the digital nerves and the flexor tendons is considerable.

It has been my practice to employ a number of incisions, selecting the one applicable to each particular case. Figure 41 indicates the various incisions that may be used. The night before operation, the hand is prepared by a careful soak in warm soap suds followed by the application of a soap poultice. A sterile bandage is applied. The operation is performed in a bloodless field obtained by the use of an Esmarch bandage. It is better to administer a general anæsthetic. The operative technique already described is applicable in the performance of this operation. In mild or moderately severe cases, the longitudinal palmar incision to one side of the contracted fascia and the lateral digital incision pictured in Figure 41, may be employed. The skin flaps are reflected, great care being exercised not to " button-hole " the skin attached to the fascial band in the palm. The involved fascia is then completely excised, including the digitations in the finger proper. I wish to stress the importance of avoiding injury to the digital nerves that are almost indistinguishable from the strands of fascia. The importance of these nerves has already been stressed. To obviate such injury it is a good plan to dissect the various fascial structures in a longitudinal direction until one is certain of their identity. After the various digital nerves have been isolated, the

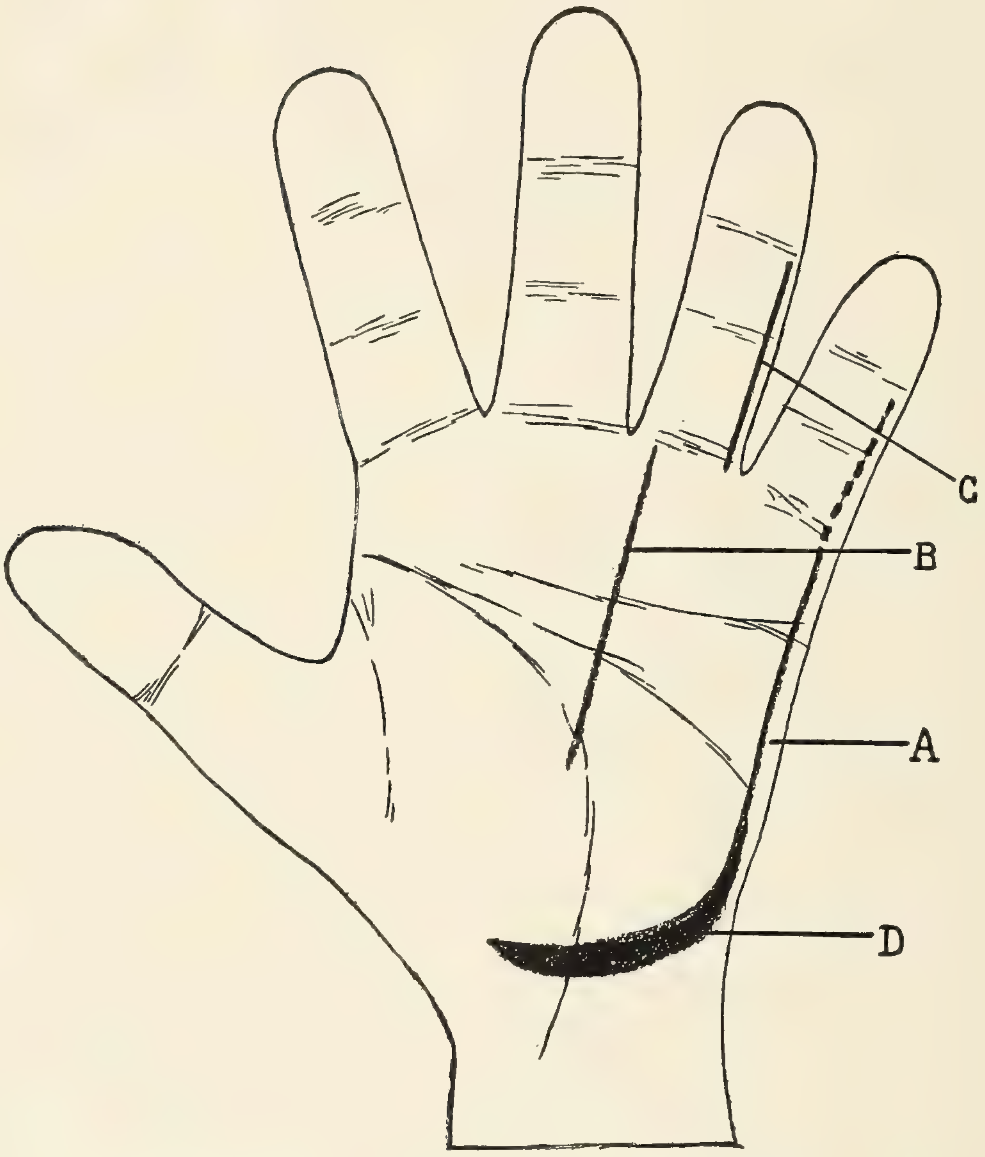

FIGURE 41. Drawing of the hand to indicate the various operations that may be performed for the radical cure of Dupuytren's contraction of the palmar fascia. "*A*" is the incision recommended by Lotheissen. A flap of skin and subcutaneous fat is dissected away from the palm and retracted externally. The underlying involved fascia is then completely excised. The incision may be extended distally along the side of the little finger, and the digitations of the fascia in this region may thus be reached. When the finger is straightened, it will be found that a slight deficiency in the wound becomes evident at the proximal extremity of the incision. This is indicated at *D*. Depending upon the size of this deficiency, will depend the treatment accorded it. If large, skin grafts should be applied. If only of small extent, it may be allowed to granulate. If both the little and ring fingers are involved, Lotheissen's incision may be combined with another on the lateral side of the ring finger, *C*. The latter is made to reach the digitations of the fascia in the finger proper. If the ring finger alone is involved, a separate longitudinal incision may be made to one side in the palm, as indicated at *B*, in conjunction with the lateral digital incision, *C*. Any combination of these various incisions may be utilized. Due consideration should be given to the blood supply of the various skin flaps produced. The key to the cure of Dupuytren's contraction is the complete excision of the involved fascia.

fascial bands may be divided transversely and excised. Careful hemostasis is essential. The skin wounds are then closed without drainage and the finger placed upon a splint in the extended position. This should be maintained for a period of three or four weeks, following which, massage may be instituted.

In more severe cases, it may be very difficult indeed to save the skin attached to the fascial bands. In such instances, depending upon the extent of skin involvement, the treatment will range from excision of the skin with undermining of the remaining skin edges and resuture, to excision of all involved skin with the application of a free full thickness skin graft or a pedunculated flap from the abdomen. In other instances, Lotheissen's incision may be used, as pictured in Figure 41. In line with the recent clinical evidence, attention should be paid to the elimination of foci of infection.

CONGENITAL MALFORMATIONS

Supernumerary digits. (Polydactylism.) By polydactylism is meant the presence of an excess number of fingers. The lesion is congenital and very often hereditary. The feet are very often involved also. The deformity may be unilateral or bilateral. The fifth finger is most often double. As many as thirteen fingers on each hand have been reported. The extra digits may be completely developed or may consist only of skin and subcutaneous tissues. The finger may have an articulation with a metacarpal or may be attached to the hand only by skin. All sorts of deformities in the region of the thumb may be encountered.

Before treatment is instituted, the hand should be X-rayed to determine the bony abnormalities that may be present. The treatment is usually simple, and consists of amputation of the supernumerary digit. In the more extensive cases, the correction of existing deformities in the remaining fingers must be undertaken, and this usually involves a number of operations.

Macrodactylia. Occasionally, one encounters instances of gigantic enlargement of one or more fingers. The condition is congenital, and may be due either to obstruction of lymph channels with the formation of lymphangiomata, or to the presence of lipomata. The treatment will depend upon the extent of the lesion and will entail excision of the tumors and plastic operations on the remaining skin. Figure 42 represents a case of congenital lipomatosis with gigantism of two fingers and the adjacent palm. A satisfactory result was obtained, after excision of the fatty tumors which were found to invade extensively between the nerves, blood vessels, and tendons. To date there has been no recurrence.

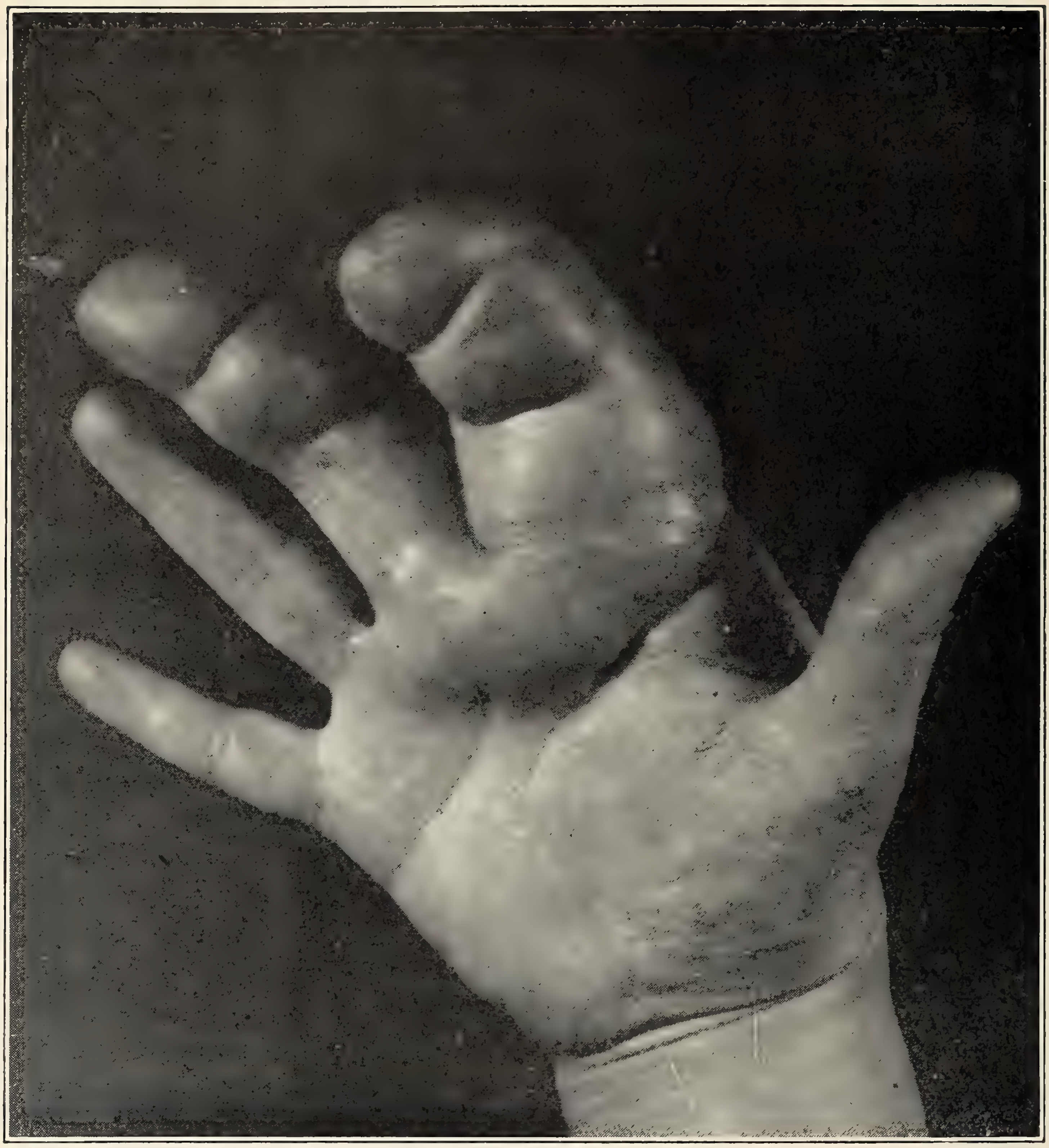

FIGURE 42. Case of congenital macrodactylia due to congenital lipomatosis. This patient was a typist by profession, and was able to use the typewriter with remarkable ease. The condition was present since birth. Operation, which was done in stages, consisted in the removal of the abnormal fatty tumors. The latter were found insinuated between the various nerves and blood vessels, rendering their dissection difficult and tedious.

Syndactylism. (Web fingers.) This congenital deformity is not at all infrequent. However, it varies greatly in extent of involvement and its anatomical distribution. The normal web between two fingers may simply be increased distally for a greater distance than found in the normal hand, or it may extend completely to the ends of the fingers. The web may consist only of skin on both sides and may permit of wide separation of the adjacent fingers. Usually, however, the web is thick, contains considerable subcutaneous fat, thus not permitting wide separation of the fingers, and extends to the ends of the fingers. In extreme cases, the adjacent nails may be fused, and X-ray may disclose union between the adjacent phalanges, the latter deformity being most frequently encountered in the terminal phalanx. The distribution of the deformity varies and may range from fusion of two fingers in only one hand, to union of all the fingers in both hands. An operation for the repair of this deformity should not be attempted until the patient has passed the seventh or eighth year. It should not be delayed much longer than this inasmuch as retarded development may occur if the fingers are not separated.

The successful treatment of syndactylism, is very difficult, indeed. The crux of the situation is the formation of a new web which will prevent reformation of the deformity and which will heal with a minimum of scar tissue. In operating upon this condition, great care must be exercised, in separating the fingers, not to interfere with the blood supply. Gangrene of a digit may otherwise supervene.

The operative treatment of this condition must be thought out carefully in each particular case. The extent of the lesion and the various deformities that may be present, will be the determining factors in the operative approach. The main point to remember is that the condition will reform unless an adequate web is constructed. Where several fingers are involved, it seems advisable to separate only two of them at one sitting. When the web is a broad one, allowing separation of the fingers, use may be made of the operation of Agnew. This, however, is rarely possible. In my experience, the best results have been obtained by a combination of a modified Didot operation and the procedure of Félizet. These operations are indicated in Figure 43. To form a satisfactory commissure, two pedunculated skin flaps may be fashioned, one of them on the dorsum of the fused fingers with its base at the metacarpo-phalangeal joint, and the other in the palm. The main portion of the bodies of these flaps are on different fingers, the ends are blunt, and when sutured, they lie side by side. (See Figure 43*F* and *G*.) The remainder of the web is then corrected by a modification of the operation described by Didot as shown in Figure 43*A*, *B*, *C*, *D*, and *E*. This then leaves a defect on the adjacent sides of the two fingers. (See Figure 43*G*.) Thiersch grafts are then applied to these deficiencies so as to avoid leaving any raw wounds. It is advisable to cover all raw areas in order to prevent scar tissue formation which will surely follow healing by granulation and epidermization from the sides.

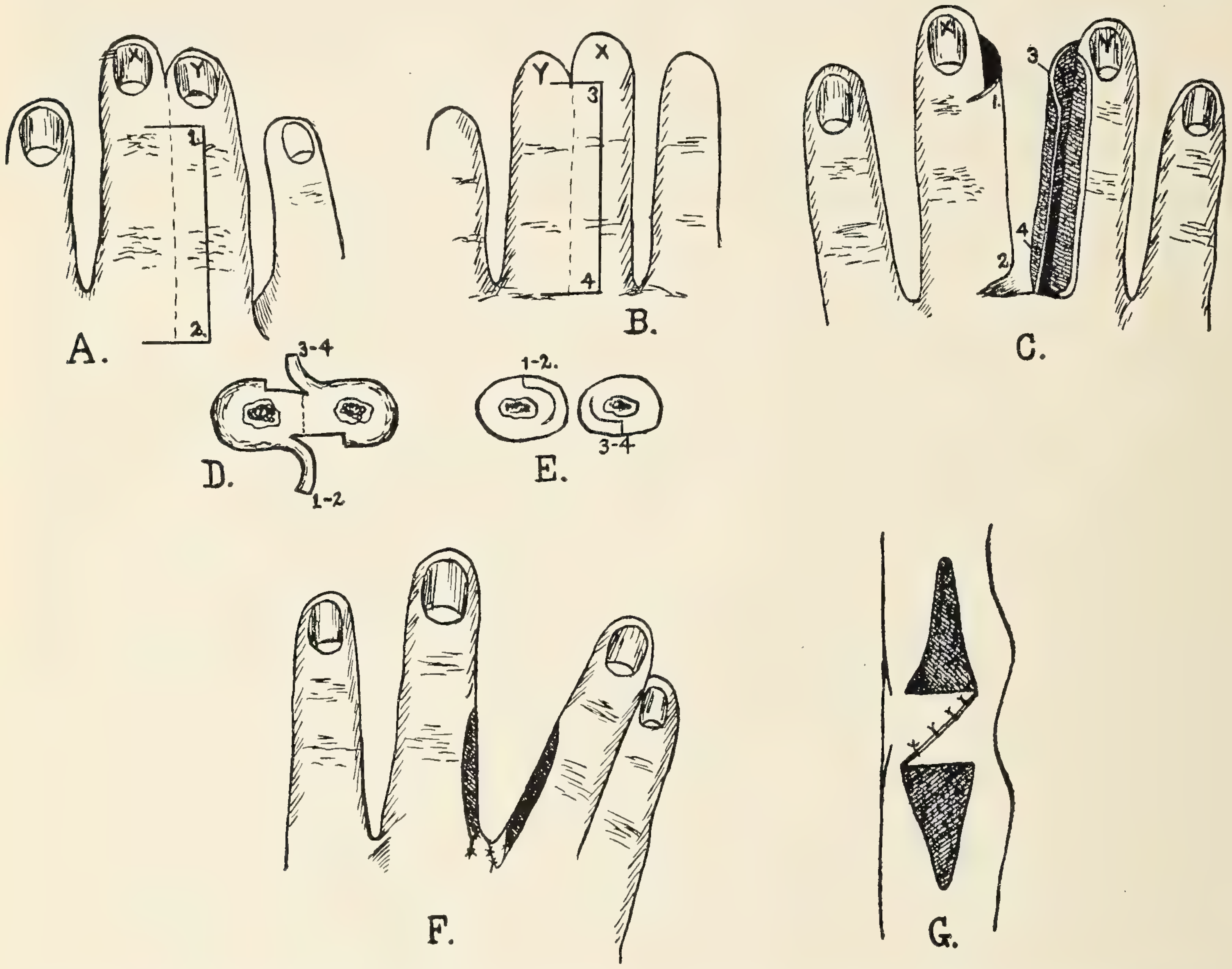

Figure 43. Drawings made to indicate the operations used for the cure of congenital syndactylism. *A* to *E* indicate Didot's operation. The anterior and posterior flaps, 1, 2, and 3, 4, are marked out and raised. The fingers are divided exactly in the midline in order to avoid interference with circulation. The skin flaps are then brought around to cover the raw surface of the finger to which it is attached, and are sutured with interrupted horsehair stitches. This is shown at *C*. *D* and *E* indicate cross sections to show the position of the flaps. Rarely, however, it is possible to perform this operation as it looks in diagram, because the flaps are usually not large enough. To cover the remaining defect, Thiersch grafts should be applied. This operation does not form a satisfactory web between the fingers. To obtain a satisfactory commissure at a later date, use may be made of the operation of Felizet. This is indicated in *F* and *G*. Two pedunculated skin flaps are raised, one on the dorsum and the other on the palm. The main portion of the pedicles of these flaps are on different fingers, the extremities are blunt, and when sutured, they lie side by side rather than end to end. The uncovered areas shown in the diagrams, must be covered with Thiersch grafts.

After the wounds are healed, systematic massage and motion should be instituted, to prevent contraction of the scars which result, after healing, along the suture lines or grafted areas. Vol. i. 729.

Syndactylism may be acquired and usually follows a severe burn, with healing of the fingers in poor position. The repair of such a deformity is more difficult than the ordinary congenital variety because of the presence of scar tissue which complicates the situation manifold. The application of the numerous general principles in reconstruction surgery already described, should aid the surgeon in solving this most difficult problem.

SURGERY OF THE HEART AND PERICARDIUM

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Table of Contents

Introduction 1241
Anatomy 1243
  Physiology 1243
  Intrathoracic Pressures 1252
  Methods of Diagnosis 1254
  Paracentesis Pericardii 1258
  Suppurative Pericarditis 1260
  Pericardiotomy for Pyopericardium 1265
  Chronic Pericarditis 1279
  Constricting Pericarditis 1281
  Decompression of Heart 1282
Methods of Exposure 1284
  Wounds of the Heart 1290
  Cardiorrhaphy 1294
  Arrest of the Heart 1296
  Displacements of Heart 1299
Surgical Treatment of Valvular Disease 1300
Surgery of the Pulmonary Artery 1301

There are many reasons why the heart and pericardium remained so long out of reach of the surgeon. It was not possible to expose either of these structures without opening the thorax, which was a closed field until new methods of anæsthesia made major thoracotomy possible. The heart is so placed as to make access to it difficult. It lies against the vertebræ and is overlaid by sternum, cartilage and ribs. This security in position has had a discouraging effect on even the most courageous of surgeons. Then it is surrounded laterally and anteriorly, except for the small "triangle of safety," by the lungs and until recently these structures created a barrier that few men had the hardihood to cross.

From the very dawn of any systematic attempt at operative therapy until the middle of the last century, the heart was considered as outside the province of the surgeon and as a result of this there grew up a tremendously portentous tradition, reaching back into the past and supported by the great names of the fathers in medicine, that to touch the heart would be followed by death. The change from this belief came about slowly and even now the chest and its contents are considered, by many physicians, as not within the practical every-day sphere of the operating surgeon.

Many factors aided in the gradual overthrow of this tradition, such as, observation of injured persons by military surgeons, homicide and suicide in civilian life, the work of the physiologist in dealing with animals and finally experimental surgery. Observers working in these different fields have shown men the way to the heart and pericardium. A very large factor in bringing this about had to do with infections of the pericardium and injuries to the heart. Effusion and trauma forced a consideration of the whole subject.

A most striking statement descriptive of the reluctance with which surgeons have approached the heart is the following made by Harry Sherman and quoted by Matas in Keen's Surgery: "The road to the heart is only 2 or 3 centimeters in length in a direct line, but it has taken surgery nearly 2400 years to travel it."

There are many great names associated with surgery of the heart. George Fisher published his monograph in 1668, and included in it all available knowledge up to that time. It was a gesture that forced interest in this entire subject on the medical profession. It was Rehn who did the first successful suture of the heart September 9, 1896. Cappelen, of Christiana, and Farina of Rome each sutured the heart unsuccessfully in September, 1895, and March, 1896, respectively. This work was made possible by Del Vecchio, who reported successful suture of the heart of dogs in 1895.

Since then, there has been a steadily increasing list of ailments and injuries affecting the heart and pericardium that cannot be brushed aside by the intelligent and conscientious physician with any peace of mind. Purulent effusions are known to be more common than was formerly supposed. Other patients suffer cardiac disability due to adhesions between the heart and percardium or between the pericardium and chest wall. Any penetrating wound of the thorax may injure the pericardium or heart. Sudden arrest of the heart may introduce an unexpected tragedy into the midst of the simplest of therapeutic measures. These and other conditions make it essential that the technique and tools of cardiac surgery be a part of the equipment of every surgical clinic.

Although diseases of the heart and pericardium concern the internist in most instances there are a number of things about these structures that are of interest to surgeons. While the heart is much the more important structure of the two, it happens that diseases of the pericardium are more amenable to surgical treatment and, therefore, occupy an important place in this field.

Anatomy and physiology of the heart and pericardium. The heart and pericardium are so intimately related that the two structures must be considered together, but at the same time, there are many conditions in which one structure or the other is chiefly involved.

The surgeon, who undertakes operation on the heart or pericardium, should have some familiarity with the embryological development of the heart, great vessels and pericardium; he should know the position and relationship of these structures and should be familiar with a number of features having to do with the physiology of the circulation and respiration.

In addition to this, he should have a good working knowledge of all of the means that are available for combating these altered anatomical and physiological conditions. To begin with, there is a pressure less than an atmosphere everywhere in the thorax, except in the lung itself. The minus pressure in the pleura is greater than that in the pericardium. The pressure in the pleura is different in inspiration and expiration and the pressure within the chambers of the heart and large vessels is different for the two sides of the heart. These pressures on the two sides are sharply altered by systole and diastole and the pressure within the veins is changed by the respiratory cycle. There are, therefore, a number of interacting agencies that require consideration.

The two pleuræ are separate and interference with the normal pressure in one may have a sharp and almost immediate effect upon the position and function of the heart and great vessels. The alveoli and bronchial surfaces of the lung everywhere communicate with the outside world and are potentially infected. In addition to the lungs and heart, the chest contains many other structures that may be disturbed by changes in position or pressure. During operative procedures, neither the heart nor lungs can be at rest and this increases the technical difficulty as well as the operative risk.

Added to all this, these structures are enclosed in a bony cage, which increases the difficulty of approach. This bony framework is made up of sternum, cartilages, ribs and vertebræ. Drainage of either the pleura or the pericardium is a very different thing from drainage of the peritoneum. If either pleuræ be opened and left open, the lung on that side will be more or less collapsed and this leaves a cavity that will become filled with either air or fluid or both and this same collapse pushes the heart toward the opposite side, bringing about, at times, grave disturbance in cardiac function.

The heart lies within the two layers of the pericardium, which is reflected on to the large vessels at its base and covers these vessels for a distance of about 5 centimeters above the heart. This carries the top of the pericardium about to the junction of the second rib with the sternum. The heart and pericardium lie obliquely in the chest a little to the left of the midline, but not nearly as far to the left as is popularly supposed, as the apex beat is produced by the extreme left side of the heart very near its tip.

As far as any surgical approach is concerned, the pericardium and heart are everywhere overlaid by the pleuræ and lungs, except a small area in front called the "triangle of safety," or "uncovered area." There is no more important consideration in some phases of the surgery of the pericardium and heart than this triangle. The two pleuræ are in contact anteriorly from about the level of the second rib to the fourth, where they diverge and produce a triangle with its base down and apex up. This triangle is a little to the left of the midline and extends down to a line just above the level of the junction of the second portion of the sternum with the ensiform. This triangle varies very little in size with respiration and may be enlarged by any forward thrusting of the heart or pericardium.

If the chest is examined transversely, it will be noted that the heart and aorta fill most of the space between the bodies of the thoracic vertebræ behind and the sternum in front, as the bodies of the vertebræ occupy a position almost in the middle of the thorax antero-posteriorly. Because of this, enlargements of the heart or effusions in the pericardium are apt to manifest themselves as lateral extensions, either to the right or left or both. The posterior curve of the great vessels acts like a spring on the heart and thrusts the apex forward and this position is usually maintained in spite of cardiac enlargement, pericardial effusion, cardiac displacements or adhesions between the heart and pericardium.

ANATOMY

The chest is bounded below by the diaphragm and above by the root of the neck. This upper boundary is indistinct. There is no anatomical separation between the chest and the neck. Many structures are common to both areas and any boundary between the two is purely arbitrary. The opening in the skeleton made by the curve of the first rib and the top of the sternum in front and laterally and the first dorsal vertebra behind is an aperture through which many structures enter and leave the thorax. For the most part these structures that pass into the thorax are found in the mediastinum, that is, that part of the chest not occupied by the lungs and pleura. The apices of the lungs extend upward into the roots of the neck, so that it can be readily seen how intricate and complicated are the anatomical relationships in this region.

THE MEDIASTINUM

We are in the habit of speaking of the mediastinum as anterior, middle and posterior. This distinction is true only of the lower portion of this space. The base of the heart is the upper boundary of the lower mediastinum. Above this line there is no such separation of the mediastinum into three spaces, but the whole mid portion of the chest between the lungs is a common one and is called the superior mediastinum. It contains many important structures: the ascending branches of the aorta, the innominate veins, the remains of the thymus gland, trachea, œsophagus, thoracic duct, phrenic, pneumogastric and sympathetic nerves and some lymphatic vessels and nodes. The top of the chest is contracted here and these structures are crowded into very intimate contact with very little areolar tissue between them.

In the region of the heart there is a sharp anatomical separation into anterior, middle and posterior mediastinum. The anterior mediastinum is a flattened space, largely potential, which lies between the anterior margins of the two lungs, behind the sternum and in front of the anterior layer of the pericardium. It contains the internal mammary vessels, the triangularis sterni muscles and some loose areolar tissue with a few lymphatics. The anterior margins of the pleuræ project into this space, but do not come in contact below the level of the fourth rib in front and it is through this space that the heart and pericardium are reached in the different midline approaches. The middle mediastinum is filled by the heart and pericardium and the beginning of the great vessels. The two phrenic nerves run along the lateral walls of the pericardium between it and the lungs. The posterior mediastinum is a space between the lungs, behind the posterior layer of the pericardium and in front of the bodies of the vertebræ. It contains the descending aorta, œsophagus, thoracic duct, vena azygos veins, the pneumogastric nerves and a number of lymphatics.

THE DIAPHRAGM

The attachments, relations and openings in the diaphragm are important. It is with the middle leaflet and central tendon that we are chiefly concerned here. The heart "sits down" on the diaphragm and the pericardium and base of the heart are anchored to it by the passage of the inferior vena cava through the quadrate opening in the diaphragm, which is placed farther forward, to the right and higher than the other openings.

In the midline in front the attachment of the diaphragm is to the sternum and cartilages of the ribs at the level of the junction of the ensiform with the second portion of the sternum. From this high level the attachment of the diaphragm to the inner chest wall curves downward and backward on either side. It must be remembered that in the middle line the merging of the leaflets into the central tendon of the diaphragm gives a somewhat stable partition wall, but the central portions of the halves of the diaphragm ascend to form dome-like structures with the concavity downward and these domes change sharply in position during respiration and as the result of pathology in the chest or in the upper abdomen.

In the surgery of the heart and pericardium the diaphragm is of prime importance for a number of reasons. The base of the pericardium is firmly attached to it and at this point of fusion the inferior vena cava penetrates both the diaphragm and posterior layer of the pericardium to enter the heart. This anchors both the heart and pericardium, but anchors them to a mobile structure. In pericardiotomy for pyopericardium the diaphragm is the barrier against contamination of the peritoneum. The ridge in the posterior layer of the pericardium, made by the inferior vena cava where it comes through the diaphragm, is the division between the two posterio-lateral recesses of the pericardium. In the midline thoraco-abdominal approach to the heart the anterior portion of the diaphragm is cut through in getting a good exposure of the base of the heart.

The internal mammary arteries, one on either side, arise from the under surface of the subclavian artery opposite the thyroid axis. Each one enters the chest behind the cartilage of the first rib and descends along the inner surface of the anterior wall of the chest just behind the cartilages of the ribs and close to the lateral margin of the sternum. The distance from the sternum above is on the average one and one-half centimeters, but as the artery approaches the diaphragm it is somewhat farther away. At the level of the sixth intercostal space it usually divides into two branches, the musculo-phrenic and the superior epigastric. At this point it is about two and one-half centimeters from the edge of the sternum. It is usually accompanied by two veins.

EXTERNAL MARKINGS

The sternum, ribs and cartilages are the external landmarks in the surgery of the heart and pericardium. While these structures usually conform to the average, there are considerable variations. The sternum varies in width and length. It may protrude as a ridge or from a depression. Its thickness is not constant and the angle made by the cartilages with the ensiform varies within considerable limits. The ensiform is not constant in length, width or movability.

The cartilages of the upper five ribs are constant and separated by intercostal spaces of about the same width. The sixth and seventh cartilages have an intercostal space between them at some distance from the sternum, but near the sternum they are usually joined. The cartilages of the eighth, ninth and tenth ribs are joined together and in turn attached to the cartilage of the seventh rib, which is the lowest cartilage to reach the sternum directly. Any deformity of the spine, such as kyphosis or scoliosis, may alter the relationship of these bony structures to the heart and the heart may be displaced by a number of conditions that produce deformity of the bony chest wall.

POSITION

The heart and pericardium are placed obliquely in the chest, in the middle mediastinum with the base of the heart directed upward, backward and to the right and with the apex directed downward, forward and to the left. The left side of the heart is rotated to the front. The base of the heart is at the level of the second interspace in front and the apex of the heart is at the level of the left fifth interspace about six to eight centimeters from the margin of the sternum. In the third, fourth and fifth interspaces the right side of the heart projects from one to two centimeters beyond the right margin of the sternum. About one-third of the heart is to the right of the midline.

In health the pericardium follows closely the movements of the heart and the pericardium and heart occupy almost the same space, except that the pericardium extends upward on the great vessels for a distance of two and one-half centimeters above the base of the heart. It is only when the pericardium becomes distended or thickened that its boundaries extend for any considerable distance beyond the heart.

THE DEVELOPMENT OF THE HEART

The following description of the embryology of the heart was written by Dr. Carl L. Davis, Head of the Department of Anatomy in the University of Maryland.

The pericardial cavity appears as a multilocular horseshoe shaped space developed within the sheet of mesoderm circumscribing the head end of the embryonic disc (about 1 somite stage), the two halves of the horseshoe being continuous with one another across the median plane. By expansion of this cœlomic space a voluminous pericardial cavity forms ventral to the foregut (pharynx).

The dorsal wall of this cavity has meanwhile become raised from the underlying pharyngeal wall, forming symetrically paired cardiac folds, from which the myocardium and visceral pericardium are formed, hence its name, myoepicardial mantle.

Simultaneously with the formation of the cardiac folds, cells develop from their deep or pharyngeal surfaces. These cells (angeoblasts) separate from the myoepicardial mantle and uniting with one another, form paired endothelial networks, the primitive endocardium. The paired endocardial primordia are continuous cephalad, as paired aortic trunks. Caudally they join the primitive vitelo-umbilical veins.

Very early during development (2 somite stage) atrial, ventricular and bulbar components of the cardiac folds are recognizable as segments separated by intervening constrictions. As the pericardial cavity enlarges the paired cardiac folds approach one another. First their bulbar and then their ventricular areas fuse to form paired bulbo-ventricular chambers, their atria by a like process becoming contiguous, but never fusing to form a single chamber. The underlying paired endocardial plexuses similarly fuse to form a single bulbo-ventricular tube ending caudally in paired atria. A serviceable endocardial lumen becomes established at about the seven somite stage (Payne embryo). The myoepicardium grows in, dorsal to the endocardium, thus completing the myocardial investment of the latter and forming a dorsal mesocardium which later breaks away leaving the tubular myocardium with its inclosed endocardium suspended by its two extremities within the pericardial cavity.

The heart tube now becomes strongly bent in a reverse curve simulating a letter "S", the bulbus forming the upper arm, the greatly distended ventricle the cross portion and the atria the basal arm. The atrio-ventricular juncture has meanwhile become greatly constricted forming the atrio-ventricular canal. By further growth of the ventricle the atria are pushed dorsally and as they expand are forced into the more proximal pericardial region where eventually as right and left atria they protrude ventrally on their respective sides of the bulbus cordis. The proximal part of the latter is taken up into the common ventricle contributing to the formation of the future right ventricle. The more distal part remains tubular forming the truncus arteriosus which by a septal growth is converted into aortic and pulmonary trunks. Coincident with these changes occurring at the proximal end of the heart, the great venous channels delivering blood to the atria through the sinus venosus become rearranged, so that all the venous blood enters the right atrium.

Internally the single atrio-ventricular canal by a septal growth is transformed into a double channel, right and left atrioventricular channels, which become respectively the tricuspid and bicuspid cardiac orifices.

The widely communicating atria become nearly separated internally by the development of two partial septa circumscribing a valvular orifice, the foramen oval which at birth becomes functionally closed, thus completing the separation of the atria.

By the development of an interventricular septum which joins the septum of the truncus artervosus the ventricle becomes paired, its left chamber communicating with the aortic division of the truncus; the right ventricle assuming a similar relation with the pulmonic portion of the trunk, thus completing the separation of the heart into venous and arterial halves as found at birth.

PHYSIOLOGY OF CIRCULATION

The heart is covered by the pericardium and is exposed to a negative pressure. The exact cause of the heart beat is unknown. Irritability, conductivity, contractiligy, extensibility and rhythmicity are the properties of the heart muscle. Two theories are held as to the origin of the heart beat, namely, the myogenic and the neurogenic theory. The myogenic theory refers to the ability of the heart to contract in response to a stimulus originating within the muscle cells. The impulse is believed to originate within contained nerve cells in the neurogenic theory.

Ringer's solution of sodium, potassium and calcium salts has been used experimentally to keep the heart of animals beating for hours after its removal from the body. The presence of these salts is very necessary for the automatic and rhythmical contraction of the heart muscle.

In the right auricle between the openings of the vena cavæ is an area of special tissue called the sino-auricular node. Lewis calls this the pacemaker of the heart.

A bundle of special tissue called the auriculo-ventricular node is found between the auricles and ventricles. This bundle lies at the base of the septum between the auricles and extends into the interventricular septum, where it divides into two branches, one branch entering the right, the other the left ventricle. On both sides the fibers of this bundle are found beneath the endocardium. This bundle or node is called the His-Tawara node.

An impulse is thought to originate in the vicinity of the sino-auricular node and spread across the right auricle, thence, to the left auricle by way of the inter-auricular band. It is still a question how the impulse is transmitted to the auriculo-ventricular node; i. e., whether the impulse is transmitted by the way of muscle tissue or by nerve fibers.

The heart beat includes the contraction and relaxation of the auricles and ventricles. The cycle begins with the contraction or systole of the auricles, then a period of rest or auricular diastole occurs while ventricular contraction or systole takes place. Ventricular relaxation or diastole completes the cycle as auricular systole begins a new cycle.

The heart is supplied with inhibitory nerve fibers from the vagus system. Accelerator fibers are received from the sympathetic system. Stimulation of the inhibitory fibers produces a slow heart action while stimulation of the sympathetic system produces an acceleration of the heart beat. These two groups of nerves are efferent fibers from the central nervous system and experimental evidence shows they have an opposite action. The accelerator fibers are thought to have a tonic activity, because a section of these fibers produces a decrease in the heart rate.

One of the most important phases of circulation is the function of the vasomotor system with particular reference to its control of blood through small arteries and arterioles. The vasomotor system helps to maintain an efficient circulation through various tissues that are in need of a controlled amount of blood. In addition the vasomotor system helps the heart to maintain a balanced circulation by producing a continued peripheral resistance. Many types of impulses influence this complex mechanism. The vasomotor center is the fovea inferior center located in the floor of the fourth ventricle. Efferent impulses reach the blood vessels through the vaso-constrictor and the vaso-dilator fibers. Vaso-constrictors are autonomic fibers originating from the lateral horn cells and enter the sympathetic chain as preganglionic fibers. They are distributed from the ganglion as post ganglionic fibers. There is no definite proof that the vaso-dilator fibers are controlled from a general center as are the vaso-constrictors. These fibers are supplied to muscles, glands, bucco-facial region and to erectile tissue. Vasomotor supply to the coronary arteries is still a disputed question.

The vaso-constrictor mechanism has definitely been proven to keep the vessels in a state of tonic activity. Experimental evidence has shown that the vaso-dilators are not in a state of tonic activity.

The circulation of the blood may be classified into two systems, pulmonary and systemic; the pulmonary from the right side of the heart and the systemic from the left. One is dependent upon the other and a state of equilibrium must be maintained between the two systems. An increase or decrease of blood volume in the right auricle will cause a variation in the amount of work and efficiency of the right ventricle and the pulmonary system. This in turn will affect the volume discharge from the left side of the heart.

Pathological physiology is seen in such surgical affections as cardiac wounds, hæmopericardium, pericardial effusions, pericardial adhesions, mitral stenosis and pulmonary embolism.

Hæmopericardium following injuries to the pericardium and heart muscle may develop rapidly and in this instance acute cardiac and circulatory failure will follow (Heart Tamponade). The sudden increase in pressure within the pericardium causes obstruction to the filling of the left auricle, increase in pressure within the pulmonary venous system, and a fall in the systemic arterial pressure. The absence or lessening of the pulse beat during inspiration produces the so-called pulsus paradoxus.

Acute pericardial effusions present the same changes as those described in hemo-pericardium. In the infectious type of effusion changes may occur as a result of absorption of toxins in instances where the effusion is small. Sterile effusions which come on gradually do not show marked circulatory changes until large quantities of fluid have accumulated. The gradual development of the fluid allows a compensatory adjustment to take place in the circulation.

Pericardial adhesions may produce changes in the circulation by interfering with normal heart movements or by obstructing the entrance or expulsion of blood from the heart. The pathological physiology will, therefore, vary as to the type of adhesions and the picture usually seen is that of cardiac insufficiency, i. e., fall in arterial and pulmonary arterial pressures, increase in venous pressure, ventricular dilatation and decrease in the force of the heart sounds. This results in dyspnœa, cyanosis, palpitation and pulmonary œdema.

In mitral stenosis there is a narrowing of the mitral valve orifice which causes a reduction in the blood volume given to the left ventricle. The output of the left ventricle is reduced. There is a rise in left auricular and pulmonary venous pressure which in turn throws an increased amount of work on the right ventricle with hypertrophy. Clinically, there is a decrease in the amplitude of the pulse wave, rise in venous pressure with a fall in arterial pressure.

Circulatory changes following pulmonary embolism vary as to the size and position of the embolus. Occlusion of a larger branch of the pulmonary artery causes a temporary fall in the systemic pressure. There is increased resistance in the right heart behind the clot with a rise in pulmonary arterial pressure. The unobstructed lung tissue may compensate for the affected area. Occlusion of the greater portion of the pulmonary circuit causes a great increase in resistance to the flow of blood from the right ventricle and consequently an increase in right auricular and venous pressure. The increased resistance may be so great as to produce great dilatation in the right ventricle, causing ventricular fibrillation and death.

INTRATHORACIC PRESSURES

Respiration and circulation are so closely allied that the two acts can scarcely be disassociated. We are familiar with the normal variations in intra-thoracic and intra-pulmonic pressures during the act of respiration. Our knowledge of blood pressure changes with inspiration and expiration dates back to the work of Hales in 1733. Experimental evidence shows that each phase of respiration causes a marked variation in the pulmonary arterial pressure. Systolic and diastolic pressure falls in the act of inspiration and rises during expiration. Accurate observations of pressure variations in the pulmonary venous circuit during respiration have not been made in the closed chest.

The pleural cavities are potential spaces having an average pressure of −4 mm. of mercury. During inspiration, the ribs are elevated and the diaphragm contracts (flattens), producing an enlargement of these potential spaces. The increase in the size of these spaces produces an increase in the negative pressure to approximately −7 mm. of mercury. There is a corresponding fall in the systolic and diastolic blood pressures. In quiet respiration the relaxation of the thoracic muscles, with the aid of diaphragmatic relaxation, causes a diminution in the size of the chest cavity. This action forces air from the trachea and we have a decrease of the negative pressure to approximately −3 mm. of mercury. The systolic and diastolic pressures rise during this act. The normal respiration is then an act that attempts to make the pressure within the chest equal to the pressure that exists outside of the thoracic cavity. The pressure within the trachea, bronchi and lung cells is known as the intra-pulmonic pressure.

The heart and mediastinal structures are exposed to the intra-pulmonic pressure through the lung walls. Howell states, "These structures are exposed to a pressure (intra-thoracic) equal to one atmosphere minus the amount of the opposing pressure exerted by the expanded lungs." The left auricle is by reason of its anatomical relationship to the œsophagus, exposed to some extent to atmospheric pressure.

The intra-thoracic pressure may have a marked increase in its negative quality due to collapse of a portion of the lung. This may come about as the result of complete obstruction to a bronchus. The corresponding lung cells will collapse because of the rapid absorption of the air contained within them. The potential pleural space is made larger and an increase in negative pressure results. This is the only condition due to changes in pressure within the pleura that causes retraction of the lungs and heart toward the affected side. An angulation obstruction may be produced in the great vessels entering the heart. Because of the collapsed lung, there is also an increased resistance to the flow of the pulmonary arterial blood.

In closed unilateral pneumothorax, according to observations by Lilienthal and Amberson, there is displacement of the heart and mediastinal structures toward the normal side in deep expiration, providing the mediastinum is not fixed. This is directly the oposite of the movements of the heart and mediastinum in open pneumothorax. Therefore, in injury to the heart and pericardium with an associated closed pneumothorax, the heart and mediastinum would be found displaced to the normal side if an x-ray were taken during deep expiration. This is an important observation.

Injury to the pericardium or heart with an associated lung injury may bring about a trapped or valve pneumothorax, causing a marked increase in intra-thoracic pressure. The injury to the lung may allow air to escape into the pleural cavity during each inspiration. The wound in the chest wall may be of such nature that the air in the pleura cannot escape. A pneumothorax of tremendous positive pressure would result. Even without cardiac injury, this condition is of a serious nature and produces cardiac embarrassment. Subcutaneous emphysema is not common in cases of this character. Emphysema beneath the skin is more commonly seen in cases of spontaneous rupture of the pulmonary alveoli beneath the visceral layer of the pleura. There is usually no change in intra-thoracic pressure. Air, in this event, follows the course of the great vessels of the mediastinum and emphysema and is first seen above the clavicles at the root of the neck. The process may extend from the neck to the subcutaneous tissues of the thorax and abdomen.

There is no evidence, so far as we could find in the literature, of any measurements having been made of the pressure within the pericardium. In a recent paper we reported measurements taken on the dog. In five dogs an average pressure of −10 mm. of water was found by using the Harvard manometer. It is logical to suppose that there is a negative pressure in the human pericardial sac. We used a needle with curved point in performing paracentesis pericardii on these dogs.

METHODS OF DIAGNOSIS

The internist, roentgenologist and surgeon should work together in the diagnosis of diseases of the heart and pericardium. All members of the group should have a considerable understanding of the anatomy and physiology of these structures. The modern group method of the study of patients has done much to break down the barriers that formerly set surgeons in a group apart and nothing has done more to improve results in surgery than coöperation between anatomist, physiologist, pathologist, bacteriologist, internist, roentgenologist and surgeon. Even when every aid is invoked and every ally called upon, the diagnosis and decision as to treatment in diseases of the heart and pericardium remain disturbingly uncertain.

The roentgenologist is a valuable consultant in this field. He can tell the size, shape and position of the shadow made by the heart and pericardium. A study of the x-ray will often confirm the impression that a pericardial effusion is present. Sometimes he can make out that the auricles are relatively more dilated than the ventricles and he may venture the opinion that it is the left auricle, chiefly, that is enlarged, as in mitral stenosis. He can confirm the belief of the internist that the right heart is more dilated or hypertrophied than the left, or the opposite.

His accuracy in the localization of radiable foreign bodies is little short of uncanny and in displacements of the heart consideration of the roentgenogram often makes clear whether one is dealing with pleural effusion, mediastinal masses, fibrosis of the lung or atelectasis.

In the study of the two types of chronic pericarditis, a small heart with a limited range of motion is indicative of a constricting pericarditis, while a hypertrophied heart associated with intercostal tugging suggests crippling adhesions between the pericardium and chest wall.

If paracentesis pericardii is to be done, observation of the pericardial shadow will help in the determination as to the best site for introduction of the needle. Indeed, the careful roentgenologist by fluoroscopic study may be willing to say that the large shadow seen in the cardiac area is probably due, in part, to effusion within the pericardium, because he cannot see clearly the beating of the heart.

By careful measurements of the roentgenogram, enlargements of the heart are accurately mapped as to the degree and direction of the enlargements and moderate displacements or rotation may be differentiated from enlargements by study of the plate and fluoroscopic observation.

CONGENITAL MALFORMATIONS

There are a number of congenital defects that may have a serious or fatal effect upon the ability of the heart to function properly. These are dextrocardia, ectopia cordis, defects in the inter-ventricular septum, patent foramen ovale, patent ductus arteriosus, stenosis of the aorta, stenosis of the pulmonary artery and congenital valvular disease.

As a rule, more than one defect occurs and often one malformation is an attempt to make good another defect. Dextrocardia has been discussed under displacements of the heart.

Up to the present, very little has been done surgically to correct any of these conditions. In ectopia cordis attempts have been made to place the exposed heart in a better position or to cover it with flaps made from the chest wall. These operations have not been successful, because of infection and because such a procedure usually presses upon the heart and disturbs its action.

It would seem that ligation of a patent ductus arteriosis might be done, but no report of such an attempt has been found. Patent foramen ovale is fairly common and "blue babies" are seen by practically every obstetrician. If the wall of one auricle could be invaginated by a finger and the opening in the inter-auricular septum thrust up under the wall of the other auricle, an incision might be made in the auricle, hemorrhage controlled by pressure and a purse string suture placed about the margin of the opening and tied and the opening in the wall of the auricle closed by ligature or suture. These babies or young children are very bad risks, but some attempts will, sooner or later, be made to correct this disabling and usually fatal condition.

In 1913, Doyen operated on a young woman with congenital stenosis of the valve of the pulmonary artery, but lost his patient during the operation.

In 1924, a child with ectopia cordis was born in the obstetrical clinic of the University Hospital in Baltimore, and I am indebted to Dr. L. H. Douglass for the following description.

The mother, a colored primipara, was admitted to the hospital at term. Her family and past history, her blood Wassermann and physical examination were all negative. She had had a normal pregnancy. Delivery was spontaneous.

The baby was born alive and cried almost immediately. The head and extremities were normal, but the anterior thoracic wall and the wall of the upper portion of the abdomen had failed to unite in the median line. This allowed the heart to protrude. All the chambers of the heart could be clearly defined and one could see and feel them pulsate. Below, and slightly to the right of the exposed heart, was a rather large and indefinite mass which was thought to be the liver and a part of the intestines covered by a coating of peritoneum. The umbilical cord was attached to this lower mass.

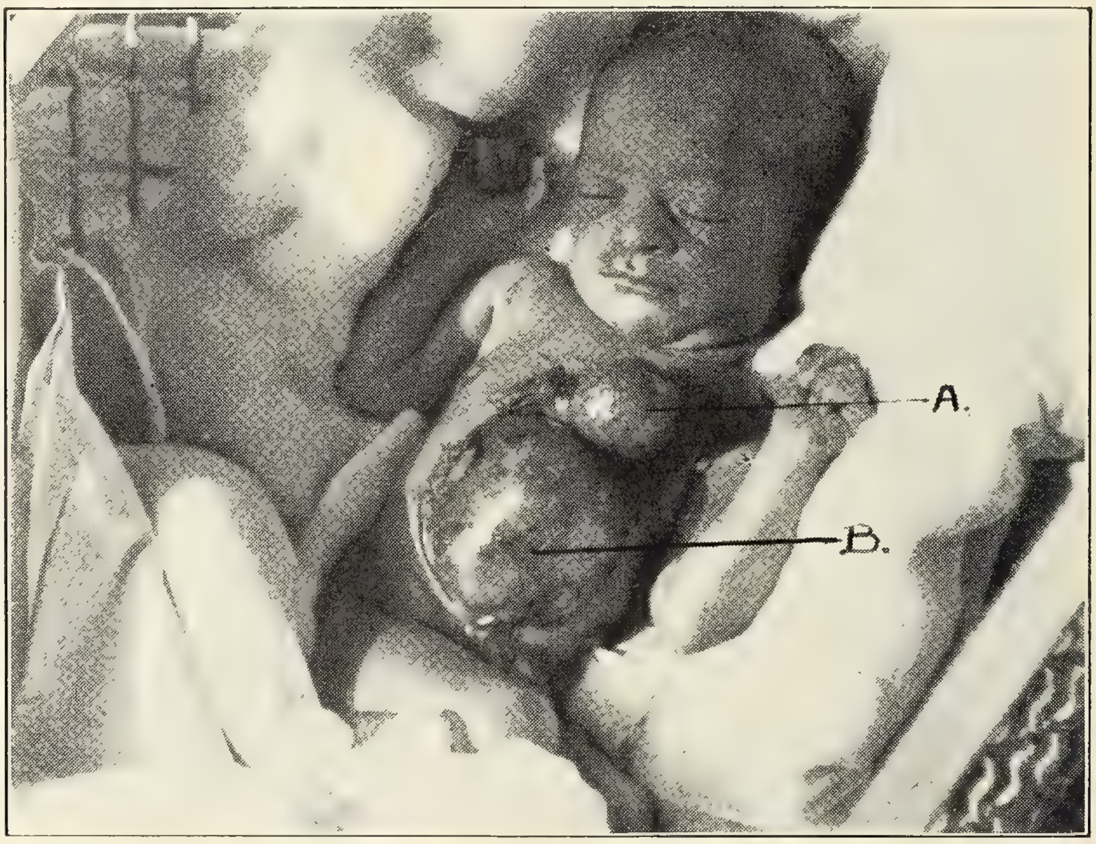

FIG. 1. Photograph of new born child with ectopia cordis.
A. Exposed and protruding heart covered by pericardium.
B. Large defect in anterior abdominal wall.

An attempt was made to drop the exposed organs back into normal position and to approximate the ununited wall, but this proved too great an embarrassment for the heart, the baby becoming extremely cyanotic. It was then decided to let them remain outside. The child was kept in a warm bath for several hours and then put in a very warm room. It nursed very poorly and the cry became progressively weaker. At the end of 30 hours all pulsations ceased and the baby died.

The following roentgenological report was made by Dr. Henry J. Walton: "The examination shows the bony skeleton to be intact, all twelve ribs are present on both sides. There is some flaring out of the ends of the upper ribs on the left side, otherwise the bony structures appear normal. There are 7 cervical, 12 dorsal and 5 lumbar vertebræ.

Both lungs are well areated. There is a marked protrusion of the heart shadow outside of the chest wall in front and to the left. There is also marked forward protrusion of the liver and upper abdominal contents.

INJURIES OF THE PERICARDIUM

It is surprising that the pericardium is so rarely torn in crushing injuries of the chest. There are only a few reported cases of laceration by bone fragments. Most of the trauma is produced by gunshot or stab wounds. It is quite likely that in many instances injury to the pericardium is not discovered in penetrating wounds of the chest where there is no injury to the heart and no considerable hæmopericardium. Many of these patients recover, where there is no serious injury to other chest structures.

In sucking wounds of the chest, the heart and pericardium are displaced and serious circulatory disturbances have to be dealt with, but injury to the pericardium itself is usually not a part of the trauma.

Foreign bodies in the pericardium, usually a missile of some sort, have been reported quite often. There will be laceration of the parietal pericardium and sometimes bruising of the heart muscle or a gutter wound of the heart seen without actual penetration into one of the chambers of the heart. Such foreign bodies should be removed. Very often there is an associated injury to the lung and pleura, in which case intercostal thoracotomy with the use of a rib retractor gives the best exposure of these injured structures.

As mentioned elsewhere, Lilienthal has called attention to the difficulty of localizing such a foreign body with the x-ray, because of the displacement of chest structures due to hæmothorax. If laceration of the pericardium is discovered at operation, with or without heart injury, it has been the custom of many surgeons to leave a small drain in the pericardial sac, because of the likelihood of later effusion producing heart tamponade. Such a procedure has two risks — the production of adhesions and infection. Some surgeons advise leaving one or more small openings in the pericardial suture line through which fluids may escape. This seems a wise precaution. Post-operative aspiration of the pericardium may be done and has been done successfully, but it is an anxiety-provoking manœuvre. It is much safer to aspirate fluid from the pleural cavity and blood or serum in the pleural cavity is much less damaging than in the pericardium.

There is very little likelihood that pus, blood or serous fluid escaping from an opening in the anterior wall of the pericardium will reach the posterior mediastinum. When the pericardium is opened through the "triangle of safety" in the anterior mediastinum for pyopericardium, it is not necessary to suture the pericardium to the subcutaneous tissues to prevent the percolation of pus into the other mediastinal spaces.

PARACENTESIS PERICARDII

Aspiration of the pericardial sac is a procedure about which a considerable controversy is taking place. Should puncture of the pericardium be done? And if so, what approach should be used?

Many surgeons take a decided stand on the negative side, but this is offset by the experience of other men, both surgeons and internists who have experienced no serious mishap in a considerable number of patients. The use of the aspirating needle is attended by unexpected accidents in all conditions of the chest where its use is indicated. Nowhere is this more true than in the pericardium. In all effusions into the pericardium, the heart is apt to lie up close to the anterior chest wall. This is true of that part of the heart that lies immediately under the "triangle of safety," so that a needle thrust directly through the pericardium in this area will be apt to injure the heart, unless great caution is taken. It is very difficult to say in any given case that the heart is not adherent to the pericardium. A number of surgeons have reported finding the heart always directly against the anterior layer of the pericardium. My own experience in ten cases of pyopericardium operated on supports these findings.

If the needle is thrust slowly inward, engagement of the point into the adherent pericardium or heart muscle will manifest itself at once by movement of the needle. There are a number of reports of aspiration of blood from the heart with a high mortality following this mishap. Death usually occurs within two hours. Serious hæmopericardium may be caused by injury of the heart wall without penetration into either ventricle or auricle. The needle is fixed by the chest wall, through which it is passed and the rapidly moving heart across the point of the needle may tear into either the heart muscle or into a branch of the coronary vessels. Bleeding into the pericardial sac will be confined, as the needle is too small to allow any escape of blood from the pericardial sac and tamponade is apt to manifest itself. By close observation and early diagnosis with prompt interference the heart may be released and the bleeding point secured.

Because the heart lies rather snugly between the sternum in front and the bodies of the vertebræ behind, effusions are apt to collect lateral to the heart, especially if the amount of fluid is large. There are three potential recesses in the pericardium. The inferior vena cava as it pierces the diaphragm and pericardium forms a ridge in the posterior layer of the pericardium. Lateral to this ridge and on either side, there is a cul de sac in which fluid is apt to collect. These are spoken of as the left and right posterior lateral recesses. Aspiration of these spaces is not safe, because they lie lateral to the auricles and auriculo-ventricular sulcus. Tearing of these structures is easy.

If aspiration is to be undertaken it should be done either lateral to or just below the ventricles. In large effusions the pericardium is pushed away from the heart for a considerable distance on both the right and left sides. Some men prefer aspirating in the fifth or sixth intercostal spaces some distance from the sternum in order to obviate the possibility of injuring the internal mammary vessels. The objection raised to this method is injury to the pleura. The anterior margin of the lung is not apt to be injured, as it moves freely within the pleura, but the anterior margins of the two pleuræ are fixed in their relationship as they overlay the heart and aspiration so far out is lateral to the "triangle of safety."

If the effusion is a non-infectious one, no real harm is done in the majority of cases, even though the pleura be traversed, but if there is any question as to the nature of the effusion such an approach is not without risk.

There is a third potential cul de sac in the pericardium and this is at the base of the sac just anterior to its attachment to the diaphragm. This occupies the position of the base of the "triangle of safety." When the pericardium is empty and the outer layer not adherent to the chest wall this recess does not exist and the pericardium follows the heart in its movements, but when there is free fluid in the sac there is apt to be a collection in this potential space.

It is this cul de sac that most men who practice paracentesis pericardii try to reach. There are a number of advantages for this route. The apex of the heart is thick and the ventricles do not extend to the point; the blood vessels in the heart are smaller near the apex and it is possible to aspirate here through the "triangle of safety" without injuring either pleura or lung and the internal mammary vessels lie farther away from the sternum here and are smaller. Aspiration should be done close to the sternum to avoid the internal mammary vessels and in the fifth or sixth interspace, pointing the needle downward, backward and slightly inward in the fifth interspace and backward and slightly inward in the sixth.

There are two other anxieties in diagnostic or therapeutic puncture of the pericardium. The effusion may be pocketed by adhesions between the two layers of the pericardium and it is not possible to diagnose the presence or position of these areas. These pockets are not apt to be present in serous effusions, but are often found in purulent pericarditis. The other anxiety is the difficulty that is sometimes met in making a clear cut differential diagnosis between pericardial effusion and dilated heart. This latter condition sometimes gives an x-ray shadow very like that produced by effusion.

Altogether, paracentesis pericardii is not without considerable risk of mishap, but the evidence does not warrant condemning this maneuver in large effusions where there is every reason to believe the collection of fluid is a serous one without infection being present.

If pyopericardium is suspected and especially if the x-ray shadow is not large, pericardiotomy is the safer procedure and more and more the drift is toward this method of approach rather than the more uncertain puncture with an aspirating needle.

SUPPURATIVE PERICARDITIS

This condition is more common than the records would indicate. The evidence is that many cases are overlooked. Osler stated that in spite of the clear cut clinical picture, probably no other serious lesion is so often overlooked. Stone found purulent pericarditis in 44 out of 300 autopsies performed on patients, who had died of pneumonia and on none of whom an operation had been done. In spite of this, in a report made by Dr. Nathan Winslow and myself, in which the literature was reviewed to May, 1927, we could find only 118 reported cases to which were added 10 new cases reported for the first time.

The organism found is usually one of three, — the pneumococcus, streptococcus or staphylococcus, in the order named. Occasionally other bacteria are found, either as a mixed infection or alone.

The age incidence is interesting. Of the 128 cases mentioned above, the largest proportion were under thirty, 69 or more than half were under twenty years of age and only 5 were older than forty.

The avenues of infection are varied. Sometimes the infection is directly from without through a stab or gunshot wound. In a number of instances the infection extended to the pericardium directly from the lung or pleura. In many instances the infection in the pericardium complicates a distant focus of infection, such as osteomyelitis and, at times, it is a part of the pathology of pyemia. Pneumonia or empyema, or both, are often associated with pyopericardium. In nearly two-thirds of the reported cases, pyopericardium was associated with some infection of the respiratory tract.

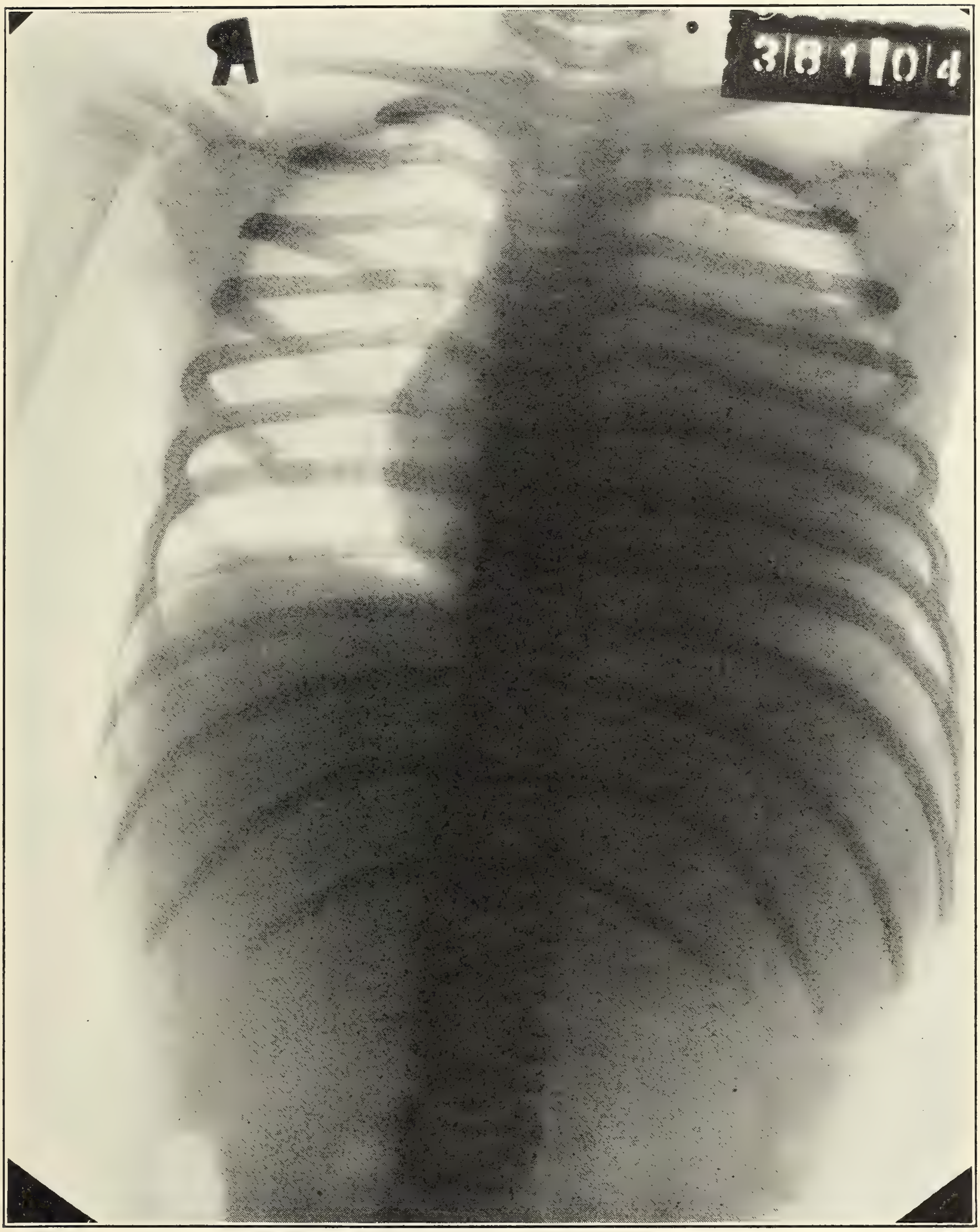

FIG. 2. The usual roentgenogram of a moderately large pericardial effusion. The pericardial shadow is enlarged chiefly to the left and this is especially noticeable in the region of the left second and third ribs.

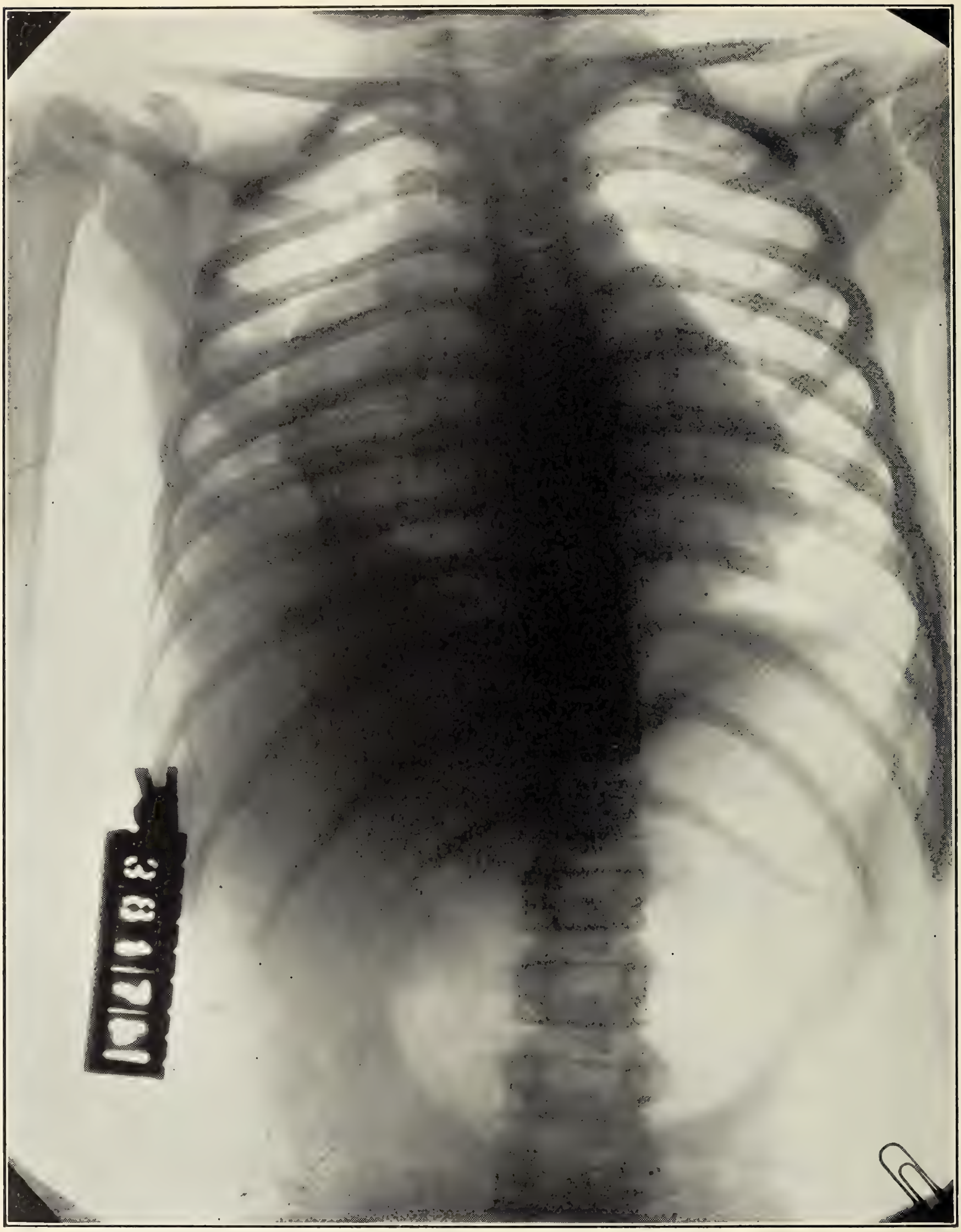

FIG. 3. Roentgenogram of child with pericardial effusion. Note the wide extension of the pericardial shadow to the right.

The amount of pus present varies within wide limits. Tamponade of the heart is not so important or urgent a condition, as in hæmopericardium. In many cases it is the infection, rather than the mechanical pressure of the fluid that is doing most of the damage. This is not always the case, however, as the amount of pus present may be large and immediate relief follow its removal. Sometimes the pus is shot forcibly from the pericardium when the sac is first opened. At times, however, the pus is so thick and tenaceous as to make its removal difficult, even through a large opening in the pericardium.

The character of the pus differs widely. In the very acute cases, complicating infections in the lung or pleura, the pus is apt to be thin, hot and blood-tinged. One is apt to associate this kind of exudate with the streptococcus. If the pus is greenish yellow and odorless, with flakes of fibrin, the pneumococcus is suspected. If pyopericardium develops as a complication of osteomyelitis or pyemia, the staphylococcus is apt to be the organism found. The earlier the operation, the more likely is the pus to be thin and the less likelihood is there that adhesions will be found. This makes drainage easier and is an important factor in prognosis.

The signs and symptoms are inconstant with a few exceptions. In diagnosis the most useful confirmatory help is the x-ray. Ordinarily the heart shadow is triangular with the base up and the outline of the heart is quite clear-cut, the apex is seen to the left of the sternum and the shadow of the apex is quite narrow.

In pyopericardium there is usually a broadening of the heart and pericardial shadow downward. If the effusion is abundant the shadow is distinctly characteristic, but if the amount of pus is small the x-ray may not be so helpful.

One would expect the heart sounds to be indistinct and many reports state this as a fact, but the apex of the heart is usually found up against the anterior layer of the pericardium and this may give a misleading clearness and nearness to the sounds of the heart. The pulse is usually quickened and the heart action weakened. There are very few blood pressure records, but those that are recorded show low pressures. Shortness of breath and cyanosis are commonly present, especially on exertion. These symptoms are apt to be increased on coughing. If a friction rub between the pleura and pericardium can be made out, it is a useful point in diagnosis. Friction between the two layers of the pericardium is a fleeting and uncertain sign. It is well to remember that the pericardium is rarely uniformly distended; that the pus has a tendency to accumulate in pockets and the two layers may, at some place, be in contact, even when there is a considerable and damaging effusion.

The paradoxical pulse should be fairly constant, but it is not always present. Some bulging between the cartilages may be seen in children, where there is a large effusion, but this sign is not often seen. The usual symptoms of suppuration are present to a varying extent — fever, sweating, exhaustion and leucocytosis.

The outstanding symptoms are cardiac distress and shortness of breath with alterations in the quality of the heart sounds and enlargement in the area of pericardial dulness made out by percussion and confirmed by roentgenograph. In any infection, but especially one in the lungs or pleura if the above symptoms persist, suppuration within the pericardium should be suspected.

In the 128 cases mentioned above diagnostic puncture was practiced on 86 patients, without evidence of injury to the internal mammary artery, to the peritoneum or to the heart. Occasionally the pleura was traversed. In 15 cases diagnostic puncture was not attempted and in 27 instances the report failed to mention whether the procedure was employed or not.

" The sites usually selected for puncture were the left interspaces near the sternum from the second to the seventh, inclusive, more rarely the left fifth and sixth spaces just within the outer limits of pericardial dulness, the left costoxiphoid angle, the subxiphoid route, the right fourth and fifth spaces near the sternum and the right chondroxiphoid region. Occasionally the patient was tapped more than once, for either diagnostic or therapeutic purposes, but the latter invariably failed to render lasting benefit. On the other hand, many authorities condemn the use of the aspiration needle, first, as being too hazardous and second, as unnecessary for making a correct diagnosis in the presence of the characteristic physical signs and roentgenographic evidence. If in doubt as to the nature of the disease, it is much safer, they claim, to cut down onto the pericardium and to enter this structure under direct vision rather than to jab a needle blindly into the chest with the possibility of entering the pleural cavity and thus instituting an empyema or of puncturing the heart and causing the death of the patient from hemorrhage. While there are numerous instances on record in which the heart has been punctured during an attempt to aspirate the pericardium, fortunately the accident is relatively uncommon, and, if it does occur, is ordinarily quite innocuous, but it may prove fatal (West). When a paracentesis pericardii has been definitely decided on, if pus is suspected, Pincoffs cautions that the needle should be introduced close to the sternum through the lowest possible interspace on the left side, with its point directed slightly downward and laterally so as to parallel the ventricles. Another strong objection to paracentesis is the obtaining of a dry tap, even in the presence of pus. Among others, Coutts had this experience, which tended to upset a diagnosis otherwise well established, and made him hesitate momentarily about sanctioning operative relief.

"Aspiration is valuable only when fluid is liberated, but, as has already been intimated, it may prove a hindrance rather than an asset. In this connection, the question as to the situation of the heart when the pericardium is more or less full of fluid is of some moment. Brentano, from his clinical experience, declares that in all pericardial effusions the heart lies most often right against the anterior wall of the sac even if adhesions are not present, and that in many cases there will be a fusion between the pericardium and the anterior wall of the heart. This means that the heart is generally in a position easily reached by the needle and likely to be punctured unless excessive care is exercised when the needle is introduced. On the other hand, when aspiration fails to disclose the expected pus, if the clinical signs indicate its presence, adequate surgical measures should be promptly initiated, for, as a rule, the pericardial fluid lies behind the heart and is, therefore, out of reach." (Winslow and Shipley.)

Pericardiotomy should be done promptly when the diagnosis is established, but some of the reported cases indicate a surprising ability on the part of the heart to withstand the presence of pus within the pericardium over considerable periods of time.

A number of factors influence the prognosis — the avenue of infection, the length of time during which the pus has been present, the type of organism, whether or not there is an accompanying severe infection of the lungs or pleura, the thickness or thinness of the pus and pocketing within the pericardium due to adhesions. Pyopericardium complicating pyemia or osteomyelitis gives a very bad prognosis.

The one big factor of hopefulness in this condition is the almost uniform youth of the patient; that factor added to early diagnosis and prompt surgical intervention give a somewhat less gloomy outlook to what might seem a well nigh fatal condition. " Of the 128 cases collected, seventy-one patients or 55.47 per cent. recovered; fifty-six or 43.65 per cent. died and in one case, 0.78 per cent., the outcome was not mentioned."

PERICARDIOTOMY FOR PYOPERICARDIUM

Pericardiotomy for purulent pericarditis is a very different problem from opening the pericardium in approaching the heart, or in the operations of Delorme or Brauer for adhesive pericarditis.

In drainage of the pericardial sac for pyopericardium, there are a number of factors that are important. Neither pleura should be opened, as it is important not to infect these spaces. If either pleura is inadvertently opened it should be closed by suture and pushed to one side before opening the pericardium. The pericardium should be drained, as nearly as possible, at the bottom of the sac. The position of the diaphragm and its

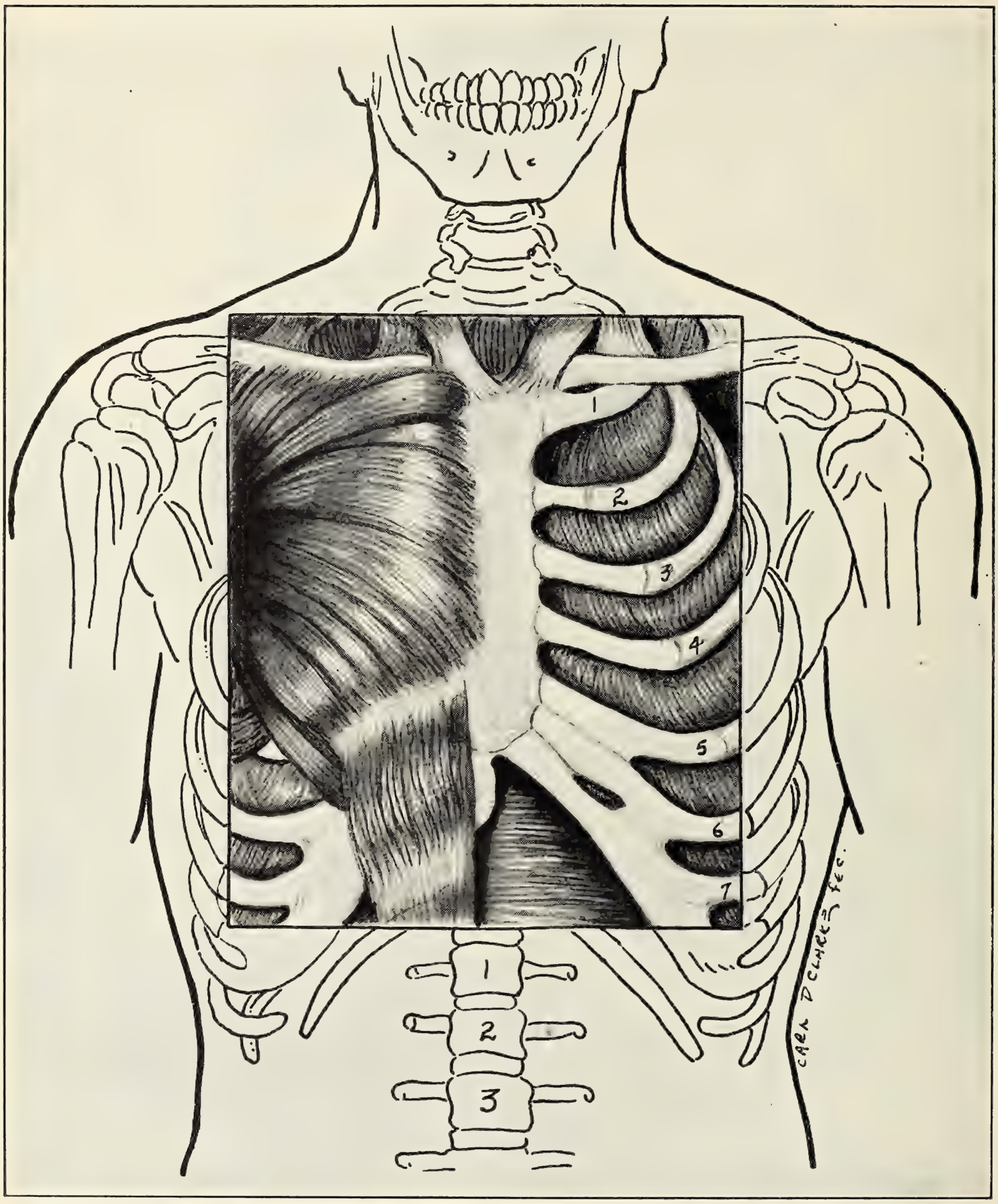

FIG. 4. Dissection showing approach to the pericardium through its uncovered portion. The fifth and sixth cartilages are not often merged, as shown in the drawing.

relationship to the landmarks on the surface of the body must be kept in mind. The " triangle of safety, " its position and size are of prime importance. This small area varies in size to some extent, depending upon

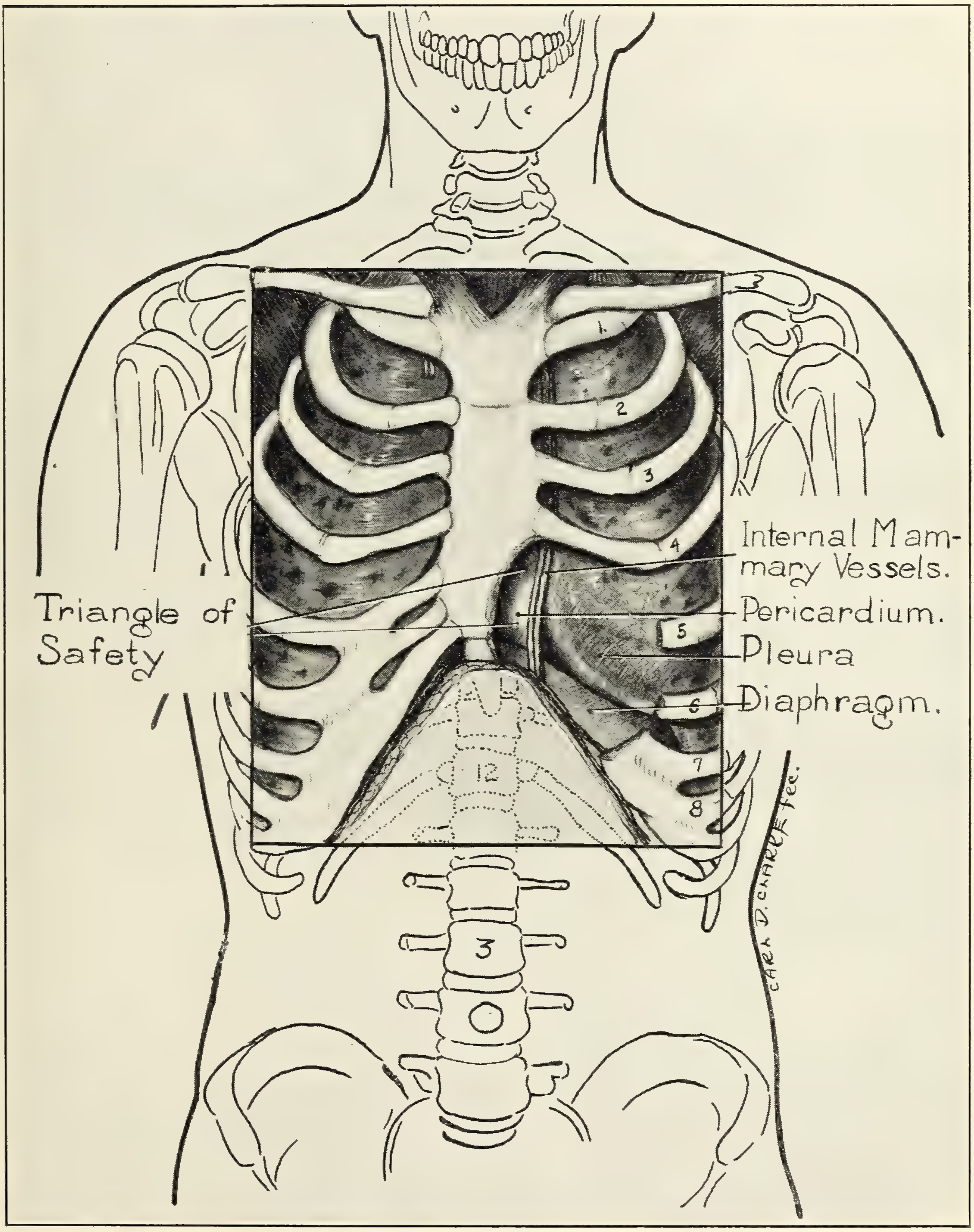

FIG. 5.

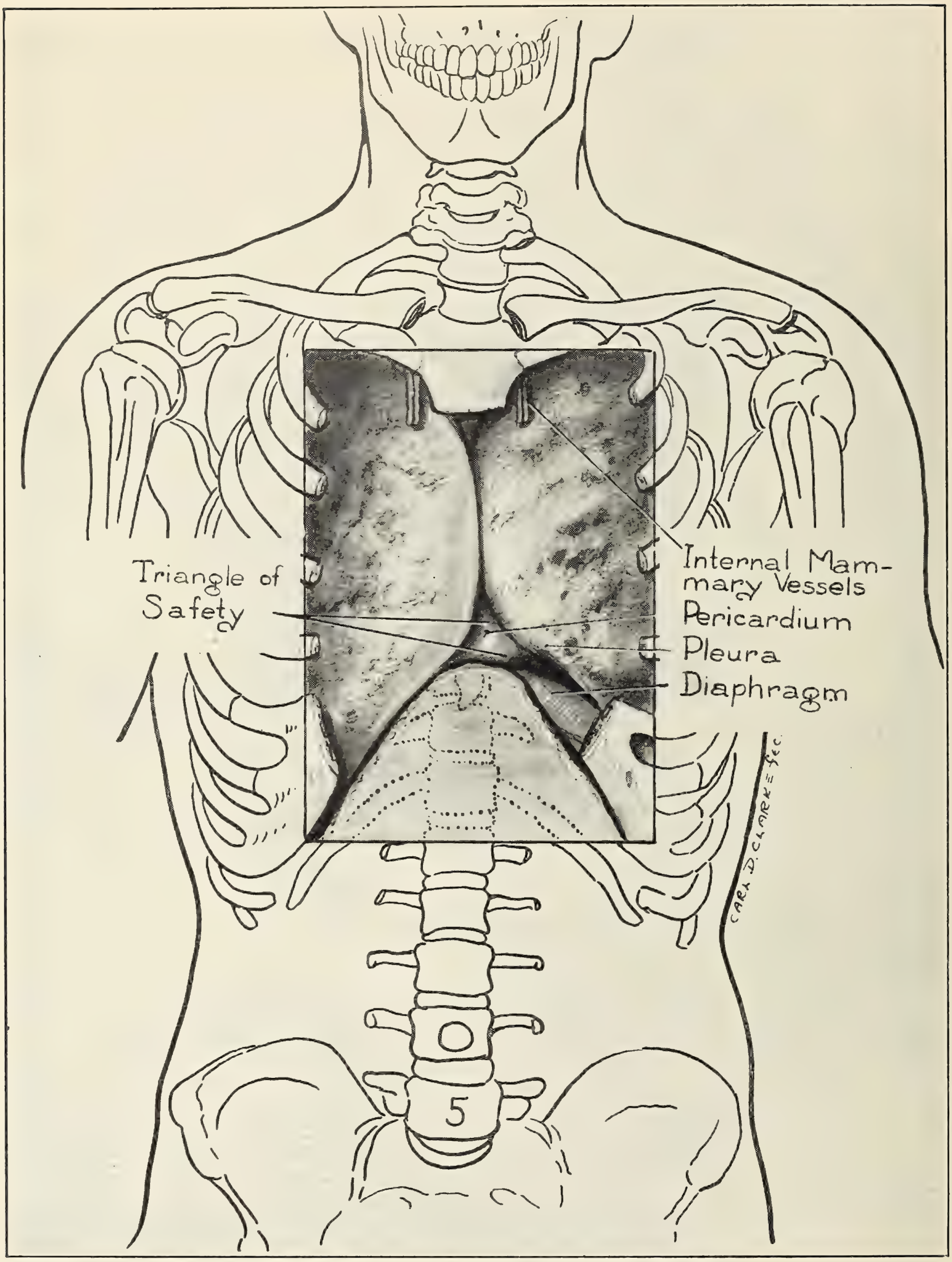
Triangle of Safety
Internal Mammary Vessels
Pericardium
Pleura
Diaphragm
5
CARL D. CLARKE fec.

Fig. 6.

the size of the pericardium. If this sac is very much distended, it may push forward and thrust itself between the two pleural sacs and widen the space that is uncovered. This phenomenon is not marked in pyopericardium and cannot be expected to help very much in making the approach easier, because the effusion is often not a very large one and the pus is apt to collect in the posterio-lateral cul de sacs. The internal mammary arteries must also be borne in mind.

After the pericardium is exposed, it is always a matter of anxiety as to whether there are adhesions between the heart and pericardium at the point where incision into the pericardium is to be made. This is all the more disconcerting, because the apex of the heart practically always lies anterior and in close contact with the anterior layer of the pericardium and can be felt by the finger. Ordinarily the centre of the enlarged pericardial sac lies somewhat to the left of the midline, but it may be pushed or pulled either to the right or left by pleural effusions or adhesions. Careful study of the x-ray shadow should be made before undertaking pericardiotomy.

A number of approaches have been used; through the sternum, to the right of the sternum, to the left of the sternum and the chondro-xiphoid. All of these give anterior drainage and the lower the opening is in the sac, the better the drainage. Posterior drainage has been considered, but the approach through the posterior mediastinum is difficult and dangerous.

"According to Heyde, the ancients practiced pericardial incision, but in the opinion of Burtenshaw, meagerness of the reports vitiates their acceptance as genuine examples of this operation. It is said that Galen removed the sternum and anterior wall of the pericardium from a soldier in whom a neglected wound of the chest had led to the development of a suppurative pericarditis and by this means obtained a cure. It is definitely known, however, that as early as 1648, Riolanus advised trephinement of the sternum for drainage of the pericardium. In 1818, Skielderup repeated Riolanus' suggestion, but it was not put into practice until 1855, when Malle evacuated a hæmopericardium successfully through an opening in the sternum. The first and only instance of drainage of a pyopericardium by this route that could be located in the literature is the case reported by Bexman, in 1891, with recovery of his patient. I have operated on four patients by this route, two recovered and two died.

"Senac, in 1794, recommended that the opening into the thorax should be made to the left of the sternum, but the operation was not attempted until 1798, when Desault endeavored to incise the pericardium in a case which had been diagnosed as pericarditis with effusion, but the condition proved to be a localized pleurisy situated in front of the pericardium.

"The first successful incision of the pericardium was performed by Romero for serous pericarditis in 1819, at which time he reported two successes and one failure following open drainage between the fifth and sixth ribs on the left side.

"The xiphocostal route was first described by Larrey in 1829. It was suggested to him by the case of a soldier in whom he had successfully drained a stab wound in the region communicating with the pericardium. The same approach was later proposed by Allingham and practiced by himself, Mintz and Rehn. Pendlebury has modified the method to the extent of resecting the sixth and seventh costal cartilages when it is thought necessary. In three of my cases this method of approach was adopted with two recoveries and one death. Of all the ways devised for doing pericardiotomy, either the trans-sternal or the chondro-xiphoid route appears to be the best; of the two, the latter is preferable, because it affords more space in which to work, insures a better exploration of the pericardial contents and provides drainage from the lower portion of the sac. Either may be performed with perfect satisfaction under local anæsthesia.

"To Hilsmann, in 1844, however, belongs the credit not only of being the first to perform pericardiotomy for pyopericardium but also of being the first to cure a patient of purulent pericarditis by this means. Six years then elapsed before the operation was repeated by Langenbeck, with an equally satisfactory result. The procedure was not undertaken again until 1879, when Rosenstein drained successfully the pericardial sac of a boy, aged 10, who was suffering with suppurative pericarditis, secondary to pleurisy. It was the report of Rosenstein in 1881, concerning this case, that established surgical intervention as the proper treatment for purulent pericarditis. Less drastic measures had been thoroughly tried out and found wanting. Drugs had proved utterly worthless. Aspiration, though affording some temporary relief, invariably failed to save the life of the patient. Notwithstanding these examples of cures and the noteworthy statistical studies of Roberts (1897), Porter (1900), Eliot (1909), Rhodes (1915) and Pool (1921), pointing out the advantages of operative measures over therapeutic agents, the medical profession has been loath to advise drainage of the pericardial sac in the presence of pus." (Winslow and Shipley.)

I have now operated on ten patients with pyopericardium; four by the trans-sternal route and six by the chondro-xiphoid. It is easy to go through the sternum with a burr and enlarge the opening with a rongeur forceps. The opening should be made just above where the ensiform joins the middle portion of the sternum and a little to the left of the midline.

Immediately behind the sternum the anterior mediastinum is exposed and when some areolar tissue is pushed aside, the pericardium is exposed in the middle of the " triangle of safety. " Because the incision is in the midline there is little bleeding and the pleura and triangularis sterni muscles and internal mammary vessels are not in the field of operation. These four patients were operated on with local anæsthesia, although two

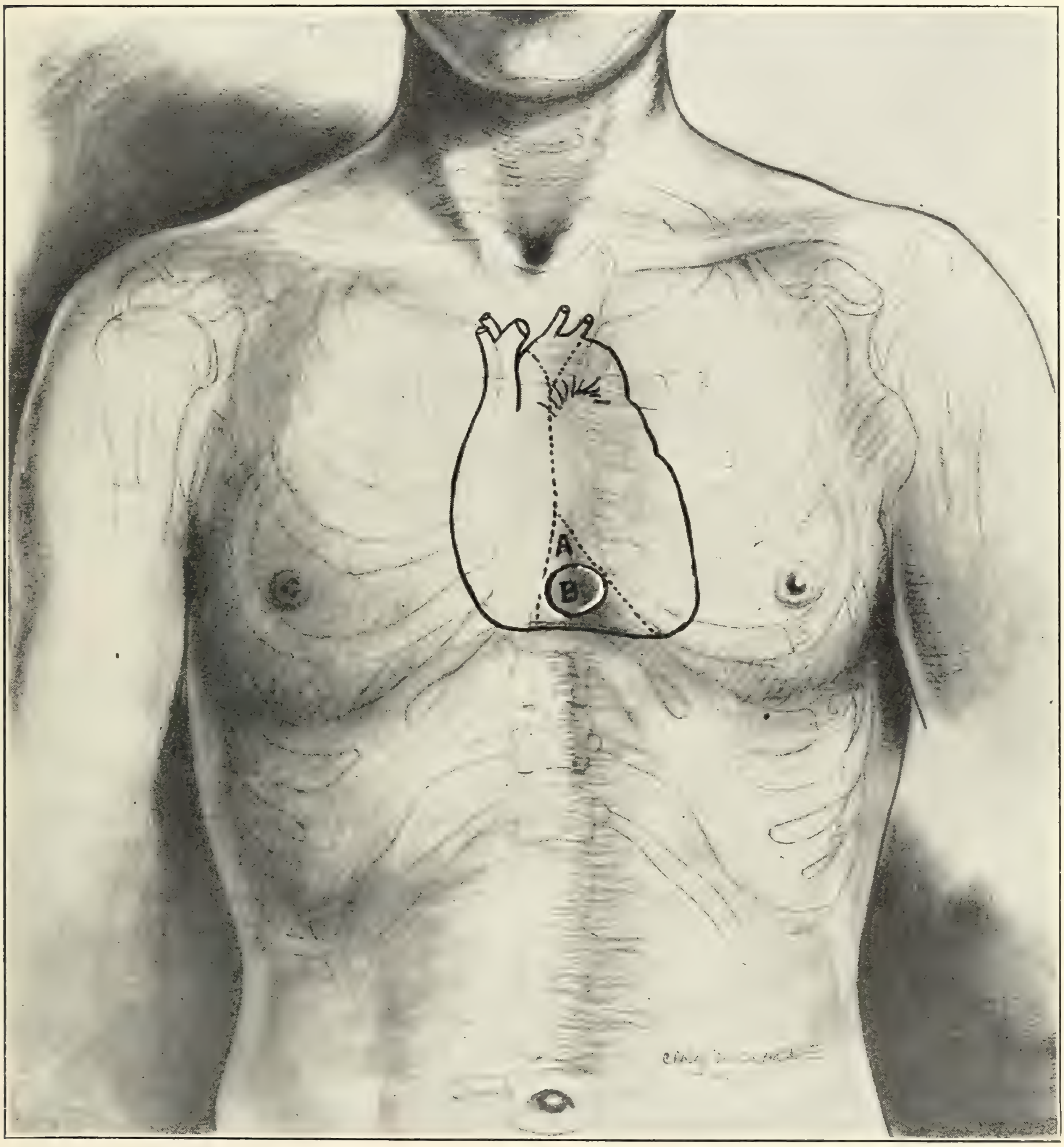

FIG. 7. Trans-sternal Approach through the "Triangle of Safety" in the Performance of Pericardiotomy for Pyopericardium.

A. Pericardium uncovered by pleura.

B. Trephine opening through the sternum.

of them were children. The operation can be done in less time by this route than the chondro-xiphoid. It is an excellent approach in children, as the finger is long enough to explore the pericardial sac for adhesions and pockets of pus, the finger of the operator being relatively longer in chil-

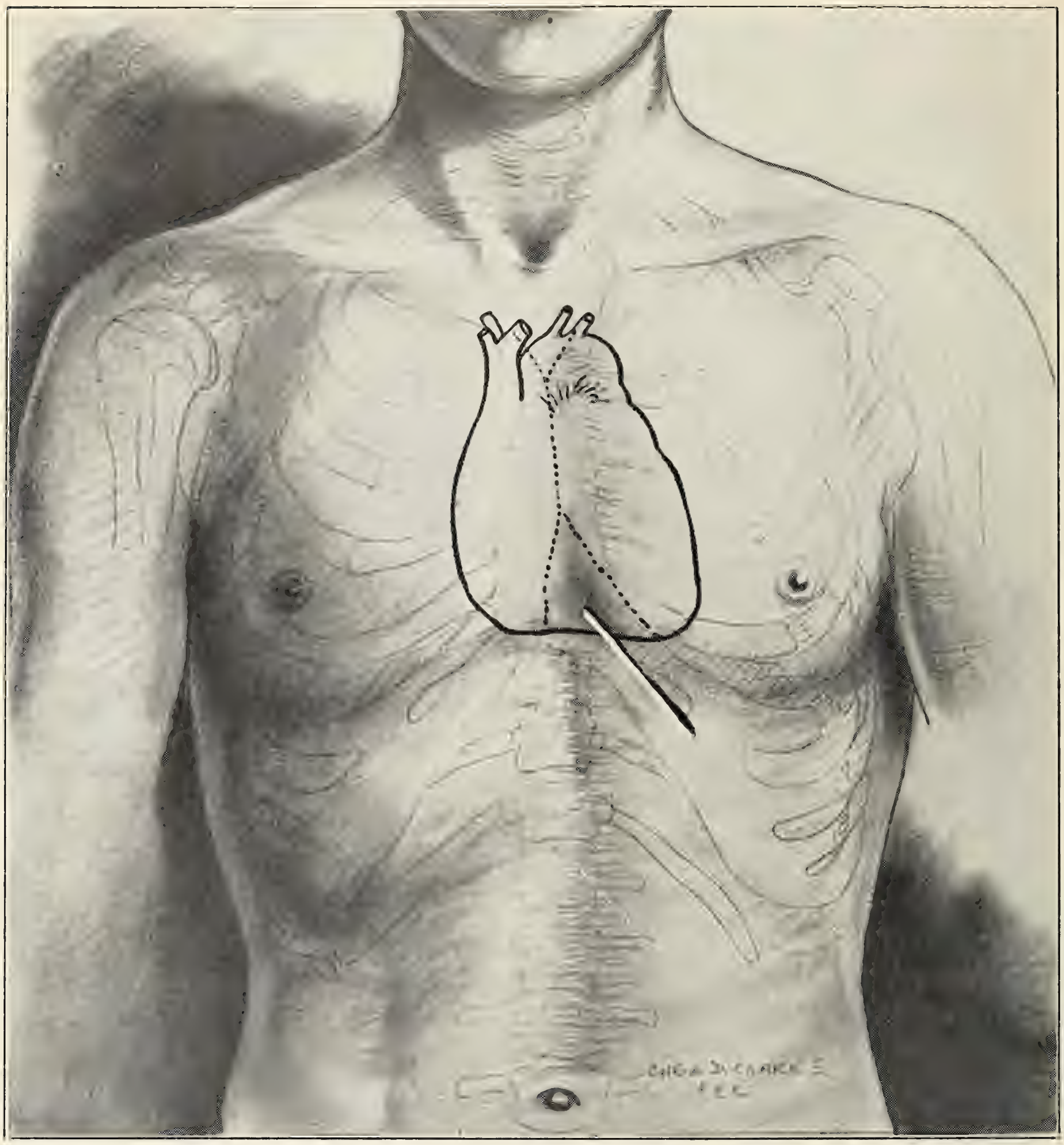

Fig. 8. Chondro-xiphoid Approach in Performing Pericardiotomy for Pyopericardium. The cartilages of the seventh, sixth and fifth ribs are resected for about 5 centimeters from the margin of the sternum and this brings the upper and inner margins of the incision over the "triangle of safety". Sometimes it is well to remove a portion of the side of the sternum. The lower end of the internal mammary vessels are usually uncovered and may be pushed aside or ligated. The inner edge of the left pleura is usually exposed and may be injured.

dren. In adults it is somewhat difficult to explore the entire sac with the finger, because of the unyielding walls of the sternum.

The left chondro-xiphoid route was used in six patients. It is somewhat more difficult and takes a longer time, the left internal mammary is apt to be in the way and may require ligature, but the opening in the pericardium is somewhat lower and the sac can be explored more readily by the finger. Some pains must be taken not to injure the edge of the left pleura where it overlaps the pericardium.

An oblique incision, 10 centimeters long, is made in the skin parallel to the left costal margin extending from the base of the ensiform cartilage toward the left. The incision should hug closely to the under surface of the costal arch and with knife and rongeur forceps about 5 centimeters of the left fifth, sixth and seventh costal cartilages removed. In two cases this approach was placed nearer the midline by biting away a crescentic piece of the margin of the sternum just above the ensiform.

When the pericardium is exposed by either of these routes it is found tense, greyish in color and opaque, in contrast to the thinner and translucent pleura through which the margin of the lung may be seen moving with respiration.

If the heart and pericardium are displaced toward the right, as sometimes is the case, then the best approach is to the right of the sternum. This approach should be somewhat higher than the left chondro-xiphoid, because the diaphragm is higher on the right. Most surgeons using this approach have either resected the fifth rib or gone through the fifth interspace. The same care must be taken as to pleura and internal mammary vessels, as in the left chondro-xiphoid. Care should be taken not to open the pericardium too high, as the top of the sac is very narrow and drainage is apt to be insufficient.

The incision into the sac is always a matter of anxiety. It is hard to pick up the pericardium with ordinary tissue forceps, because of its tenseness and because the heart action, if hurried and tumultuous, is constantly striking against the anterior layer of the pericardium. At this stage, considerable doubt may be felt as to whether or not there is any effusion. The heart seems so close to the pericardium that the impression is apt to be given that a mistake in diagnosis has been made. It is well to remember that the pus collects lateral and posterior to the heart. It is unwise to attempt aspiration at this stage for confirmation of the diagnosis, as the heart is easily injured from this central position. In ten cases, mentioned above, there were no adhesions between the anterior pericardium and the heart.

If the pericardium be grasped by two Halstead forceps and held away from the heart, it can be opened safely. There will often be a gush of fluid when the pericardium is opened and sometimes the rapid change in conditions surrounding the heart produces some feeling of distress on the part of the patient, somewhat comparable to the sensation produced by "mediastinal flutter." Whether this is due to change in the intrapericardial pressure or to the advent of air into the sac is not determined. (Beck.) This distress can often be lessened by plugging the opening in the pericardium with gauze. When the patient is quiet the finger should be gently introduced into the pericardial sac and pockets or adhesions felt for. If the adhesions are not too dense, they should be broken across. Heart arrest has been reported during this manipulation, so that very great gentleness should be used.

Drainage is a matter about which there is some difference of opinion. The pericardium should be left open. I have sutured the pericardium to the incision in the chest wall only once and do not believe it is necessary. Two small rubber tubes were placed in the sac in all the cases except one. In this patient, no drainage material was placed in the sac, as it has been shown experimentally that drainage tubes always lead to the formation of adhesions. It was believed that the heart's action would force the pus out of the sac. This patient recovered.

Irrigation is a matter about which practice has differed. Many different kinds of fluids are used. If irrigation is done, care should be taken to provide for a return flow, as trapped fluid may so compress the auricles, which are thin walled, as to seriously interfere with the circulation. Several deaths have been reported while irrigation was being done. I have been uncertain, in a number of cases, as to whether irrigation was of value. One patient complained so bitterly of pain that irrigation was discontinued and he recovered. The last patient operated on, however, was not irrigated for some days and began to improve only after irrigation removed considerable quantities of thick pus. In one case, the patient improved for two weeks and then began to run fever again with cardiac distress. X-ray showed some bulging of the pericardial shadow high up and on the left side. A finger was introduced along the drain tract in the pericardium and a pocket of pus opened and drained. In this patient the pericardial sac at this time was obliterated everywhere by adhesions, except along the drain tract and in the position oft he walled-off pocket. Yet this patient, now five years after operation, is not conscious of any cardiac disability.

"In purulent pericarditis with a moderate amount of pus present, it is likely that pressure on the ventricles is not very disturbing to the circulation, but it is known that pressure around the base of the heart interferes with the filling of the auricles, thereby raising the pressure in the veins and lowering it in the arteries. It would be interesting to know what effect the bathing of the heart in pus has on the sino-auricular node and the auriculoventricular bundle.

"So many cases of pyopericardium are overlooked that it raises the question whether it is not possible to have a serious disturbance of the circulation by an amount of pus within the pericardium too small to show any marked increase in the pericardial shadow or to give any clear physi-

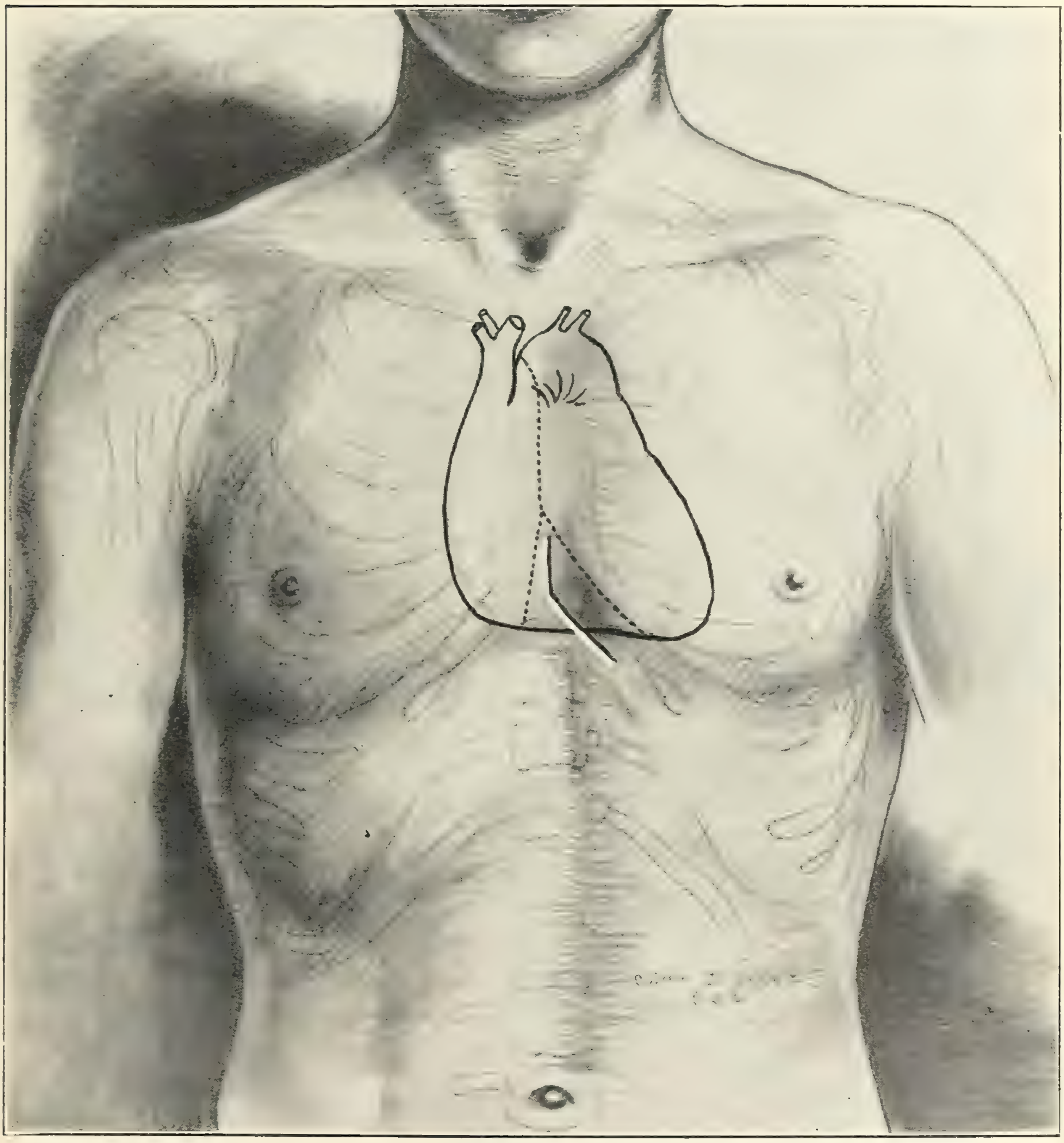

FIG. 9. Combined trans-sternal and trans-chondral approach in performing Pericardiotomy for Pyopericardium.

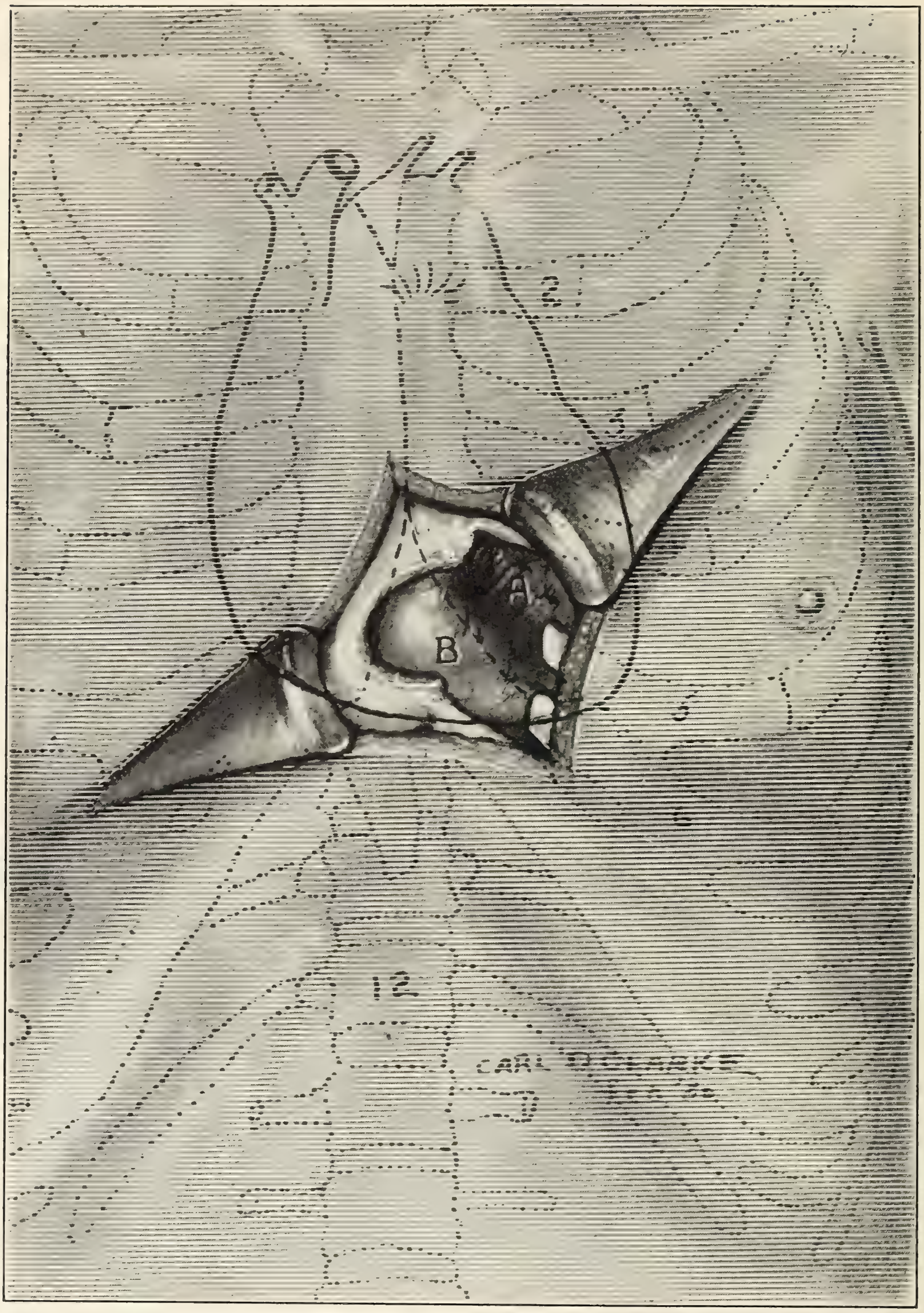

FIG. 10. Combined trans-sternal and trans-chondral approach.
(A) Pleura.
(B) Uncovered portion of pericardium.

cal signs of its presence. Holmes emphasized the use of the fluoroscope in pericarditis and expressed the belief that a pathognomonic sign is inability to distinguish the auricular from the ventricular beat.

Because the pressure everywhere within the thorax, except in the lung itself, is lower than atmosphere, one's curiosity is raised as to the effect of atmospheric pressure on the heart after pericardiotomy. Certainly the function of the wall of the chest is to maintain a negative pressure within the thorax, and it is not unreasonable to suspect that the heart may be disturbed by exposure to atmospheric pressure. We believe that closed drainage of the pericardium in purulent pericarditis might lessen some of the imperfect results following on drainage." (Shipley and Horine.)

Recently (April, 1930), one of us (A. M. S.) operated for pyopericardium complicating scarlet fever and pneumonia. The patient was a seventeen-year-old boy and the diagnosis had been made by Dr. M. C. Pincoffs, who referred the case for operation. A large, sero-sanguinous, thin effusion was found.

A combined trans-sternal and trans-chondral approach was used. We have not seen any description of this method in the literature.

An incision was made through the soft parts in the midline extending from the level of the fourth rib down to the junction of the ensiform with the second portion of the sternum and was then carried in a curve outward over the upper edge of the seventh costal margin for about 5 centimeters.

The sternum and cartilages under the incision were uncovered. An opening was made with a burr through the sternum near its left margin and opposite the cartilage of the sixth rib. This opening was enlarged by rongeur forceps and about one and one-half centimeters of the left fifth and sixth cartilages were removed. This gave a relatively large exposure through the "triangle of safety." The left edge of the pleura was seen, but was out of the way and the internal mammary vessels did not come into the operative field.

When the pericardium was opened it was easy to examine the pericardial sac for adhesions and pockets and the incision in the pericardium was close to the diaphragm.

This patient was operated on under tribromethylalcohol anæsthesia. A relatively small dose was given and was helped out with some novocaine injected under the skin. This combination produced a very satisfactory anæsthesia without discomfort or complaint and offers an advantage over general anæsthesia in unruly children and nervous adults. Local anæsthesia is preferable when it can be used.

Altogether, the trans-sternal route, although it has been little used, has the support of a number of surgeons, anatomists and pathologists and when modified as described above is an easy, rapid and bloodless way of exposing the uncovered pericardium.

In reaching the heart by the lateral chondro-xiphoid route, the seventh costal cartilage is below the level of the diaphragm and when it is removed care must be taken not to enter the abdomen. The cartilages of the sixth rib and usually of the fifth also, are removed close to the sternum. A better exposure may be gotten by biting away some of the sternum at the attachment of the left fifth and sixth ribs. At the upper and inner angle of this opening the uncovered pericardium is found. This approach begins a little below and to the left of the " triangle of safety " and the internal mammary vessels usually have to be ligated and the pleura pushed to the left.

In approaching the pericardium by the trans-sternal route in adults, it is difficult to make a digital examination of the pericardial sac, because of the relative shortness of the finger and the unyielding walls of the trephine opening through the sternum. Except for this difficulty the trans-sternal route has much to justify its use.

" Bacon's experience at the autopsy table impressed him with the comparative ease with which the pericardium may be explored through an opening in the sternum. He tabulates the advantages of this route, as follows:

1. It is anatomically correct.
2. It affords an easy approach to the pericardium.
3. It supplies the best possible drainage.
4. It permits ready inspection of the heart and pericardial cavity.
5. It is devoid of mechanical danger, such as hemorrhage and rupture of the pleura.
6. It can be done under gas anæsthesia.
7. It requires only from five to fifteen minutes for its completion.
8. It does not leave deformity.
9. It offers the least possible chance of spreading infection to the pleural or to the peritoneal cavities." (Winslow and Shipley.)

Late results after pericardiotomy for pyopericardium. There is a widespread belief that crippling pericardial adhesions are bound to follow in the wake of drainage for suppurative pericarditis. Evidence gained at subsequent operations on humans and experimental work on animals (Shipley and Horine) support this view. It is almost certain that adhesions do follow suppuration and drainage, whether drainage material be left in the pericardium or not. But the study of available reports and our own experience have shown that many of these patients will get along without evidence of cardiac insufficiency.

Just how far these early adhesions may disappear or be stretched out does not appear. The more likely explanation lies in a consideration of the separate types of chronic pericarditis leading to the distinct operations of Delorme and of Brauer. Observations on the hearts of animals show that under normal conditions the pericardium follows the heart closely in its movements and it is not difficult to understand that chronic adhesions between the heart and pericardium may not be seriously crippling to the heart's action, provided the pericardium is not constricting the heart or is in turn not adherent to the anterior chest wall.

CHRONIC PERICARDITIS

There is considerable confusion in the literature as to the nomenclature, pathology and treatment of this group of conditions. Cardiolysis is the term widely used to indicate the operative treatment. There are two distinct conditions and while one condition may merge into the other, the anatomical changes are very different and operative treatment is predicated on an understanding of this difference. Adhesions between the two layers of the pericardium are common to the two pathological pictures, otherwise the conditions are very unlike. The names of Delorme and Brauer are associated with these two kinds of chronic pericarditis.

CHRONIC ADHESIVE PERICARDITIS
CHRONIC MEDIASTINO-PERICARDITIS
CARDIO-SYMPHYSIS. PERICARDIO-SYMPHYSIS

In this group there are dense adhesions between the pericardium and the structures in the mediastinum, which are in turn adherent to the anterior chest wall. Often the pleura is adherent also. This condition is sometimes called mediastino-pericarditis and Brauer's name is associated with it. There are adhesions also between the two layers of the pericardium, but the pericarditis is not a constricting one. The etiology is usually some infection of the pericardium and mediastinum, such as rheumatic fever or acute suppurative pericarditis wherein the infection has spread to the structures surrounding the pericardium. The condition when seen is usually chronic, there is an associated myocarditis, the heart is hypertrophied and perhaps dilated and there will be evidences of myocardial failure. On inspection there will usually be seen retraction of the intercostal spaces to the left of the sternum occurring with systole. The adhesions between heart, pericardium and anterior chest wall drag against the heart during contraction and interfere with its free movement. Unless retraction is present, the diagnosis is difficult and doubtful. Sometimes the retraction is seen as far back as the mid-axillary line or even posterior to this. If the apex beat is fixed and cannot be altered by changes in position of the body, that is further evidence of the fixity of the heart. Auscultation and palpation do not help as much in the diagnosis, as the above symptoms. Fluoroscopic examination of the heart should be made in the lateral and oblique positions and a careful roentgenologist may notice that the heart is held up close to the chest wall during diastole and that there is little relative change in position of the ventricles during diastole and systole.

The heart muscle is already damaged and this double difficulty cripples the heart to such an extent that these patients are seriously handicapped. It is quite likely that the condition exists to a wider extent than its recognition would indicate. When I was a clinical clerk my roommate, the late Dr. H. L. Rudolph of Gainesville, Georgia, noticed these intercostal retractions in a chronic heart case and made a note of them and extensive mediastino-pericardial adhesions were found at autopsy. The late Dr. C. W. McElfresh commended him for his acuteness in observing this sign, but next to nothing was known of the condition at that time.

The chief difficulty encountered by the heart is in systole, as the heart muscle has to work against two forces; the arterial resistance and the dragging of the heart, because it is fastened to the chest wall. The base of the heart is fixed by the great vessels and the ventricles are fastened against the chest, so that sooner or later, the symptoms of decompensation manifest themselves. There may be an associated endocarditis and leaking heart valves may complicate the picture and obscure the diagnosis. Norris and Landis have called attention to the fact that this type of myocardial disability does not respond to digitalis.

The operative relief of this condition is the cardiolysis of Brauer, or theracolysis præcardiæ after the terminology of Kocher. Cardiolysis does not accurately express the operation, "mobilization of the heart for cardio-symphysis", is the term suggested in Bickham's Operative Surgery.

The operative approach is to the left side of the sternum over the cartilages of the fourth, fifth and sixth ribs. A soft part flap should be turned outward containing all of the tissues down to the bone and cartilage. It is well to make the vertical portion of the skin incision a little mesial to the left border of the sternum, as some portion of the sternum may have to be removed if the adhesions are extensive. After the soft part flap is turned outward the cartilages of the fourth, fifth and sixth ribs are removed and the extent of the bony resection will be determined by the size and position of the heart and the extent of the adhesions. No attempt is made to go through the pericardium or to separate the adherent pericardium from the heart. Usually the tissues just behind the cartilages and sternum cannot be recognized as separate structures. If there are adhesions to the sternum, considerable increase in the released area may be gotten by biting away some of the sternum. The object of the operation is to replace the unyielding bony and cartilaginous chest wall by yielding soft parts. Care should be taken not to tear the pleura or injure the internal mammary vessels. These structures do not often come into view, as the operation usually does not go deeper than the fibres of the triangularis sterni muscle.

An increasing number of these operations are being reported and encouraging results noted. The operation is not a particularly formidable one and may be done under local anæsthesia, unless the patient is especially apprehensive.

CONSTRICTING PERICARDITIS

This is the condition in which the operation suggested by Delorme offers a method of release. A number of terms have been used to describe this type of chronic pericarditis, — thoracolysis præcardiaca, suggested by Kocher, concretio pericardii and chronic adhesive pericarditis. Churchhill wrote a splendid report in the Archives of Surgery for December, 1929. He collected 37 operations undertaken for the relief of this condition. Although the operation was suggested in 1895 by Weill and urged by Delorme in 1898, and referred to by Carl Beck in 1901, it was not until 1914, that Rehn reported his first case. Of the 37 cases collected by Churchhill, 19 did well, 7 patients died as a result of the operation, 2 were not improved and in 4 cases the patients died later, although they survived the operation. In 5 patients the operation was not completed. Volhard and Schmieden have reported the largest number of cases (7). There may be some mediastinitis present, but firm adhesions between the outer layer of the pericardium and chest wall is not the predominant condition present.

The chief disability is due to interference with diastole of the heart caused by constricting adhesions between the heart and pericardium. Usually the pericardium is thick and fibrous and may contain calcareous depositions within its wall. Tuberculosis is sometimes the etiological factor, but in the majority of instances this condition has followed an acute pericarditis.

About fifteen years ago, a patient came to autopsy in the medical service of Dr. Thomas R. Boggs in the City Hospitals, Baltimore. This patient had chronic constricting pericarditis caused by a very much thickened, calcareous and constricting pericardium due to tuberculosis. It was the first case of this kind that I had seen and about coincided in time with Rehn's report.

Volhard gives a good description of these patients as quoted by Churchhill. The operation undertaken for the relief of this condition is a very different one from the Brauer operation for the relief of mediastino-pericarditis.

The operation of Delorme is a true decortitation of the heart and consists in the removal of enough of the constricting and adherent pericardium to release the heart. The approach may be the lateral one by resection of cartilages or the lateral trap door operation of Kocher. This does not give a very good exposure of the right side of the heart and some of the left side of the sternum may have to be resected. The left internal mammary must be secured and care taken not to open the pleura in stripping it back away from the pericardium. The Duval-Barasty operation seems very radical for this condition, but the operation recently described by Kerr and Warfield should give a good exposure.

After the pericardium is exposed and freed from the pleura it should be incised and the muscle of the heart exposed. Thereafter a very careful separation of adhesions should be undertaken and the pericardium removed piecemeal, as it is freed. This may be done by the tip of the finger, but in places scissors will be required. Calcareous deposits in the pericardium increase the difficulty. A number of serious and fatal accidents have occurred during this maneuver, but there are already a considerable number of excellent results reported and new reports will be coming in.

DECOMPRESSION OF THE HEART FOR CARDIAC HYPERTROPHY

In 1907, Morison proposed that the ribs and cartilages in front of the heart be resected for the relief of intrathoracic pressure due to cardiac enlargement where the bulk of the heart is the chief pathology present. As previously mentioned, Brauer had advised cardiolysis for mediastino-pericarditis and Peterson had done the operation in 1902. Morison's idea was decompression of an hypertrophied heart and cardiolysis was advised by Brauer for the liberation of an adherent heart from the unyielding chest wall.

Morison's proposal was made in ignorance of Brauer's and Peterson's work and Mr. E. C. Stabb of Edinburgh, operated on a youth nineteen years of age. This patient was disabled by the train of symptoms associated with hypertrophy of the heart and it was believed that some of his disability and discomfort were due to compression of the greatly enlarged heart by the chest wall. Decompression of the heart was done by resection of that portion of the cartilages and ribs that overlie the heart. The pericardium was not opened. He stood the operation well and was so much improved that he returned to work.

Graham discussed this subject in his presidential address before the American Association for Thoracic Surgery in 1928, and advised that surgical intervention be considered in individuals with cardiac insufficiency due either to chronic adhesive pericarditis or to compression of the heart due to hypertrophy.

In a paper read before the Philadelphia Academy of Surgery in April, 1929, and published in the Annals of Surgery for November, 1929, Graham reported two children on whom he operated for compression of the heart due to hypertrophy. " The fourth and fifth ribs and costal cartilages, including the periosteum and perichondrium, were removed from the left border of the sternum to the anterior axillary line."

Both of these patients stood the operation well and were improved. There was a decided lessening of the discomfort caused by the pounding of the heart against the thoracic wall. The older patient, a boy 14 years old, died later of broken compensation and the younger, a colored girl 5 years old, died of pneumonia three months after decompression of the heart.

Allen and Graham, in the Archives of Surgery for December, 1929, report their findings in experimentally produced pressure on the heart of dogs. " More than 100 observations were made on the hearts of 12 dogs. A careful analysis of the records shows that whenever the extracardiac pressure is increased, and maintained for a considerable period of time, there is a decrease in the efficiency of the heart. This is manifest by a fall in the mean blood pressure in the systemic circulation and a decrease in the pulse pressure.

This is soon compensated for, in the normal animals, by changes in the arterial system which are to maintain the normal blood pressures.

The heart remains embarrassed by the sustained increase in extracardiac pressure.

It is logical to infer, therefore, that the human heart is similarly less efficient when it is enlarged sufficiently to be pressed on continuously by the bony framework of the thorax. Decompression of such an enlarged heart should relieve the increased extracardiac pressure and would be expected to increase the efficiency of the heart." (Allen and Graham.)

METHODS OF EXPOSURE OF THE HEART

There are two main approaches to the heart, the intercostal and the transsternal, or the lateral and the median. A considerable number of operative procedures have been devised and used following one or the other route or combining the two. The midline approach may be enlarged by opening the abdomen also. The choice of route is influenced by the nature of operation to be undertaken. If the base of the heart is to be well exposed then some type of median operation should be done. In injuries to the heart where the wound of entrance is to the left of the sternum, some type of intercostal or rib and cartilage flap operation is time saving and gives a good exposure of the anterior and left sides of the heart.

The most complete exposure of the entire heart is given by the combined thoraco-abdominal pericardiotomy, known as the Duval-Barasty operation. This operation is a formidable one, but because of its central location is relatively bloodless and has the great advantage of reaching the heart without much likelihood of injurying either pleura. The abdomen is opened in the midline, from the ensiform downward to just above the umbilicus. The ensiform cartilage is excised and the diaphragm separated from the anterior chest wall, so that two fingers of the operator can be thrust into the anterior mediastinum. The skin incision is carried up over the midline of the sternum to the level of the second rib and the sternum split up to this level. The sternum is then cut transversely across, care being taken not to injure the internal mammary vessels. The sternum may be cut through with a motor driven circular saw, by heavy bone forceps or with a Gigli saw. This latter method necessitates trephining of the sternum at the upper limit of the incision. In any case care should be taken not to injure the underlying structures. As the two halves of the sternum are sprung outward, pains should be taken to separate pleura and pericardium from any attachment they may have to the anterior chest wall. Retractors are used to hold these folding doors open and the pericardium is opened through its uncovered portion, care being taken to strip back the pleura. The anterior portion of the diaphragm and a part of the posterior layer of the pericardium are then incised. The position of the inferior vena cava must be remembered. The upper abdominal contents are packed out of the way.

Kerr and Warfield in the Annals of Surgery for September, 1928, reported a combined midline and lateral trapdoor exposure without opening the abdomen. This method of approach was devised for the removal of a mediastinal dermoid, but gives a good exposure of the pericardium and heart as well.

"The manubrium sterni was trephined with a Doyen burr, as was the lower portion of the gladiolus sterni opposite the sixth interspace. The

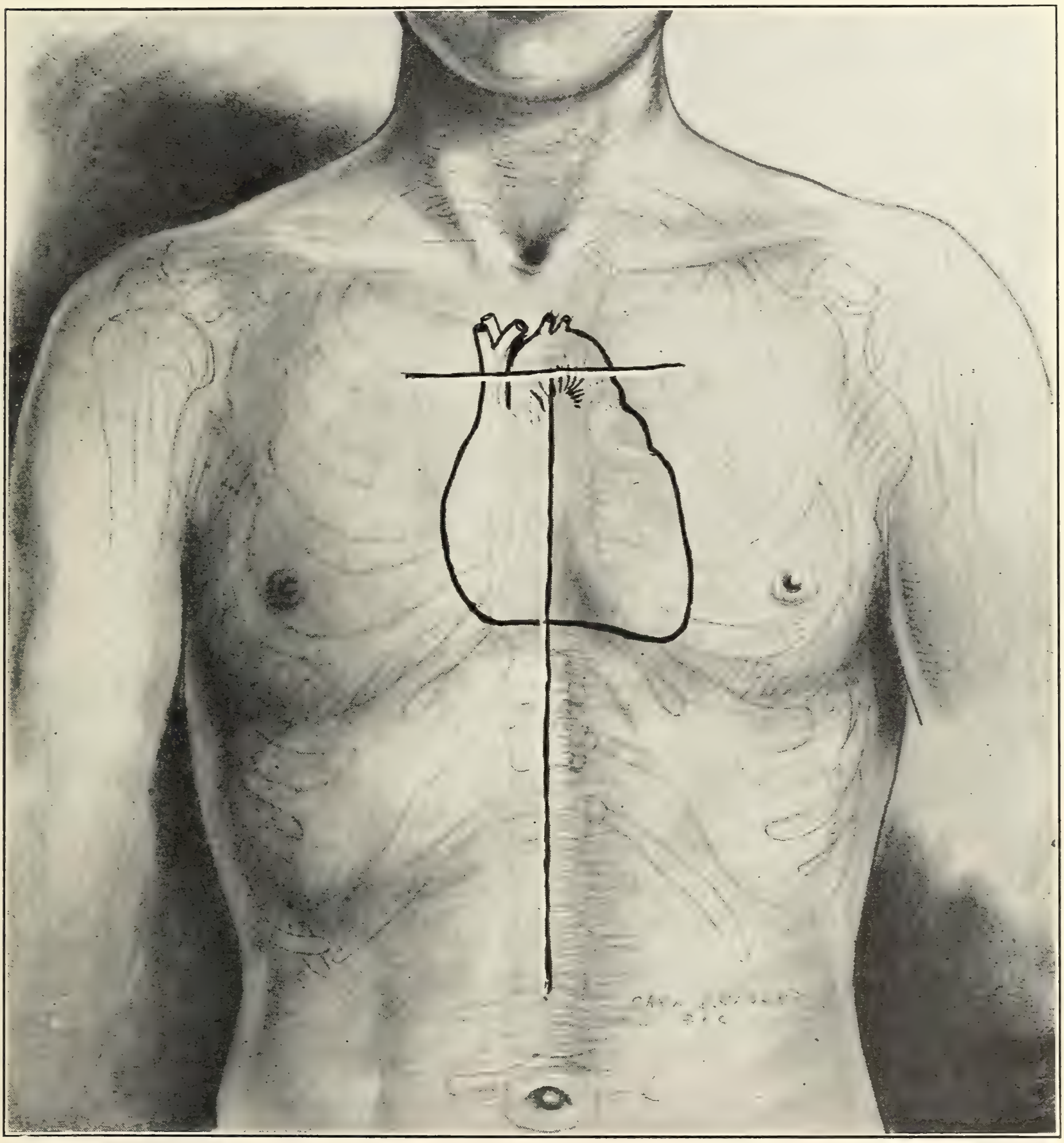

FIG. 11. The Median Thoraco-abdominal or Duval-Barasty Incision. The ensiform is removed and the sternum cut through to the level of the second rib and the sternum cut across at this level. The abdomen is opened and the two bone flaps turned outward and held in position by a rib retractor.

mediastinal contents were dissected away from the back of the sternum and a Gigli guide passed from one trephine hole to the other. The saw was passed and the sternum was split longitudinally bevelling the saw-cut

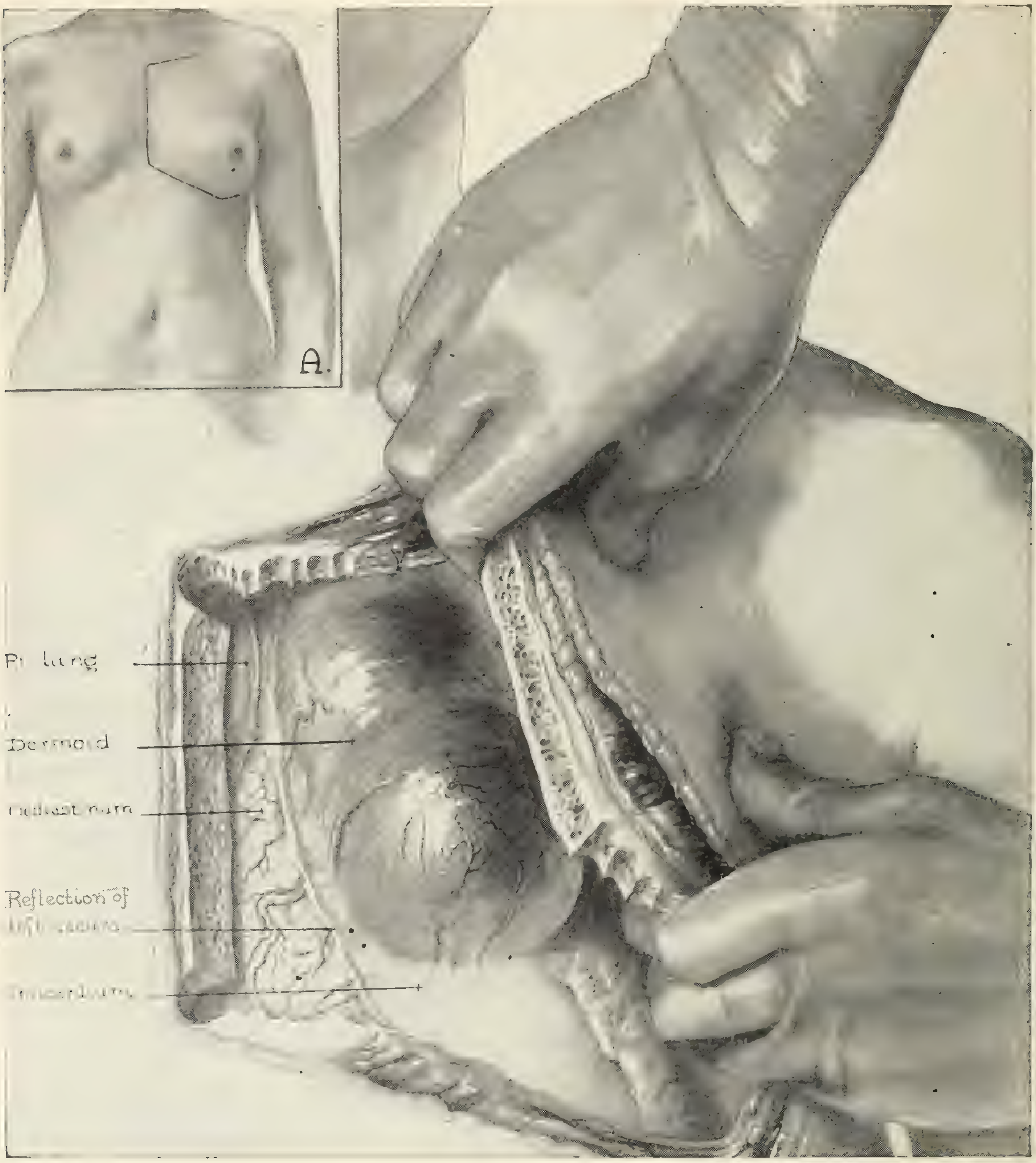

FIG. 12. A new method of thoracotomy showing bevelled incision of the sternum into the first and sixth interspaces, allowing the left half of the sternum with the ribs to be sprung open in the form of a trapdoor which gives complete access to the entire hemithorax. The thoracotomy gives ideal exposure for any intrathoracic manipulation as it exposes the mediastinum, pericardium and hylus of the lung.
(From the Annals of Surgery. Vol. 88, page 620, 1928).

sharply to the right. The two trephine openings were then connected to the first and sixth left interspaces with a DeVilbis bone cutting forceps. The anterior mammary vessels were found, ligated and divided. The skin and intercostal muscles of the first and sixth interspaces were cut midway between the ribs. On elevating the flap the reflection of the pleura from the mediastinum to the anterior chest wall was exposed and divided. The trapdoor could then be sprung open, exposing the entire left hemithoracic cavity. The tumor could be seen presenting behind the pleura. The upper lobe of the lung was adherent to the upper portion of the cyst. The pleura was stripped readily from the tumor. There was one band of adhesions from the outer aspect of the mass to the lateral chest wall. The cyst was dissected with the finger and shelled out readily, except for a firm adhesion to the pericardium which was divided with scissors. On attempting to strip the upper, outer portion of the tumor from the lung and chest wall, a portion of the cyst was opened and some cheesy material and hair escaped. The pedicle arose from the anterior mediastinal tissues where the vessels of supply to the tumor were clamped and divided. The entire dermoid was taken out of the chest with very little loss of blood. The debris was sponged out of the pleural cavity and the lung expanded by increasing the oxygen pressure to 20 milligrams of mercury. The trapdoor was closed and held in place by two kangaroo sutures passed around the sternum, through the second and fifth interspaces. A number two chromic suture was passed around the sixth and seventh ribs close to the sternum and another around the second and through a drill hole in the first rib. This effectually held the bevelled incision of the sternum closed. The superficial fascia was closed with a continuous locked suture of number one plain catgut. The skin was sutured with silkworm gut. No drain was used. Dressings were applied and the left chest strapped with adhesive plaster."

Left lateral methods. A number of incisions to the left of the sternum have been devised. Most of the operations reported for trauma to the heart or pericardium follow this route.

A long intercostal incision may be made in the left fourth or fifth interspace and a rib retractor used. The fixation of the cartilages to the sternum narrow the exposure just where it is most wanted. This can be overcome by separating the cartilages from the sternum above and below the incision. This is the Spangaro operation and is the most useful of these lateral methods of approach.

Excellent operative results have been gotten, however, by other means of exposing the heart, such as trapdoors made of ribs and cartilage swung outward or upward by resection of one or more ribs. Lilienthal advises a long seventh intercostal incision. The Kocher incision is a good trapdoor one and runs along the sixth intercostal cartilage from its junction with the rib to the side of the sternum and then upward along the left border of the sternum for any desired distance as high as the second rib. The cartilages are separated from the sternum and this flap turned out. The pleura is guarded during this maneuver and it is possible to expose and

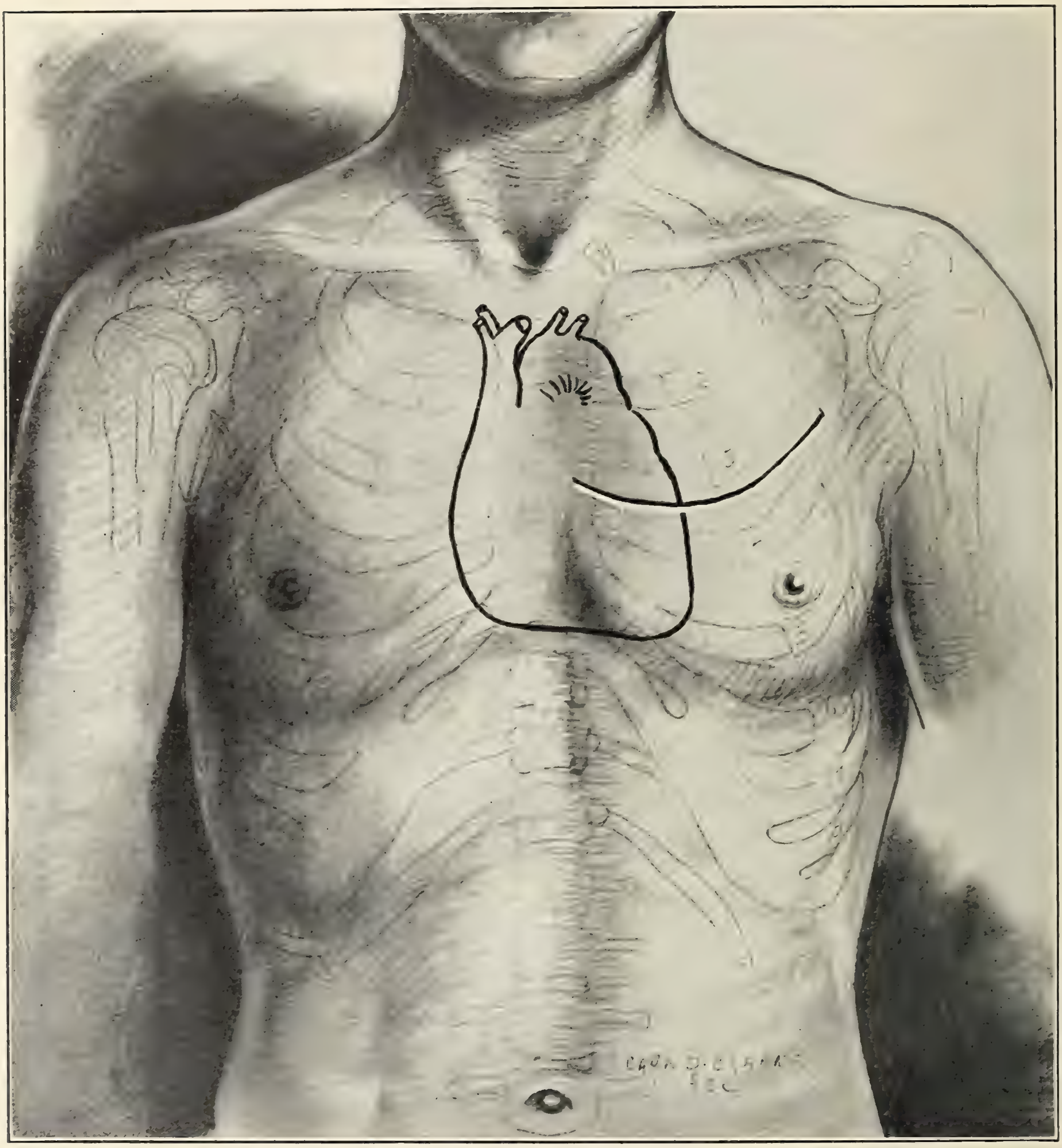

FIG. 13. The Spangaro Operation. This is the long intercostal incision and is the most used approach at the present time in operations upon the heart, great vessels, mediastinum and lungs. If the cartilage on either side of the incision is separated from the sternum and a rib retractor used, a very good exposure is gotten.

open the pericardium without opening the pleura. Before reaching the pericardium the internal mammary vessels must be ligated and the triangularis sterni muscle separated from its attachment below and turned out with the flap.

Removal of one or more cartilages and anterior ends of the ribs enables one to reach the left side of the pericardium rapidly and gives a good exposure. The disadvantage of this method of approach is the difficulty

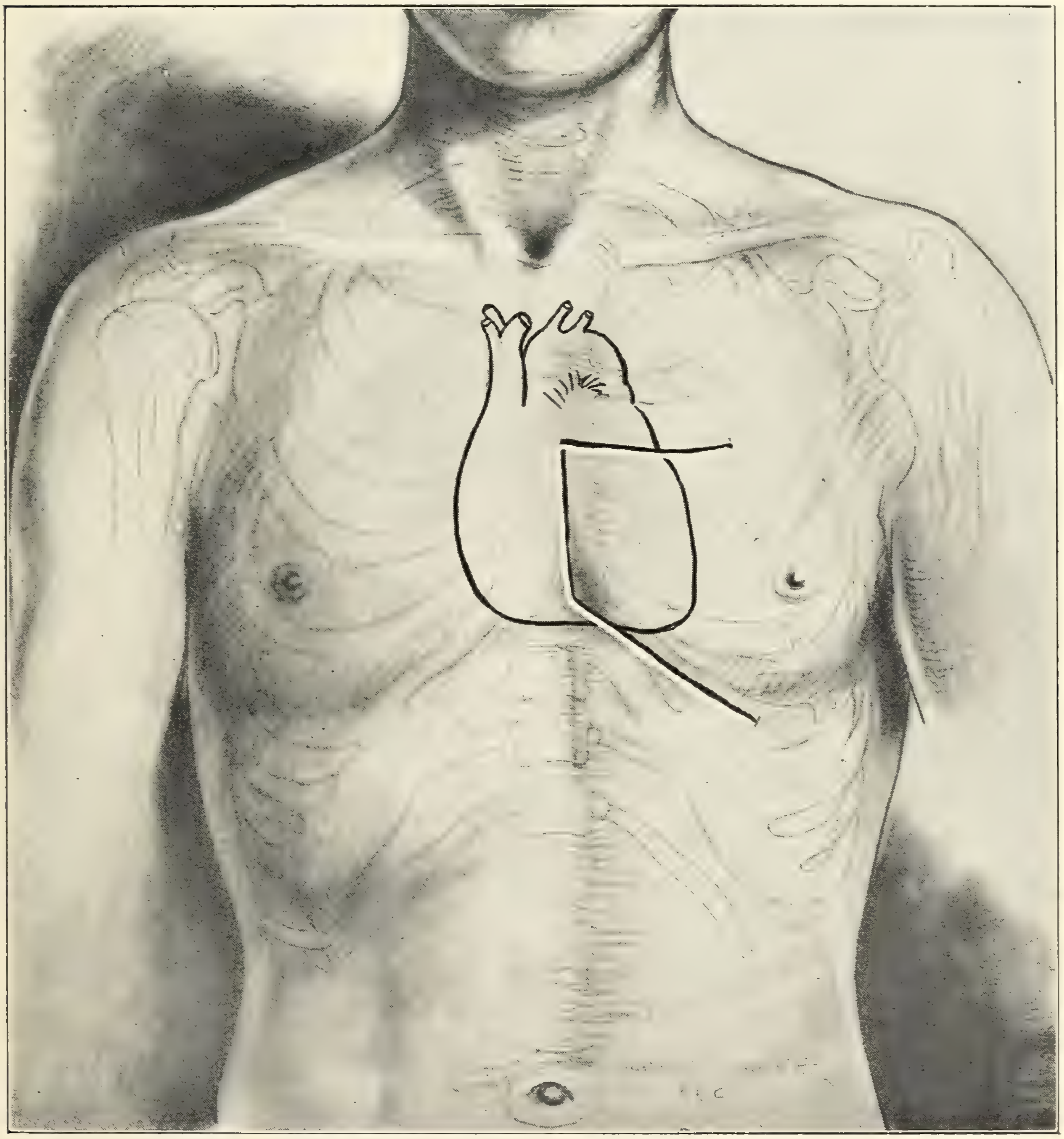

FIG. 14. Kocher's Method. Exposure of the heart by a lateral flap turned outward. The cartilages of the third, fourth and fifth ribs are separated from the sternum and a flap turned out containing the whole thickness of the thoracic wall.

encountered in making an air-tight closure. The pleura tears easily when being sutured and if the chest wall is thin, considerable time and care may be required in closing the incision snugly. In all of these lateral operations, the pleura is usually opened and this creates an extra operative hazard and increases the post-operative risk. The internal mammary vessels may cause trouble, although care in securing them will usually obviate this.

Some method for combating collapse of the lung at operation should be at hand, although this anxiety is felt less and less. Collapse of the lung takes place when the pleura is opened, but in the majority of instances does not produce any serious interference with the function of respiration. If " mediastinal flutter " should occur, however, it is a serious and menacing complication and must be met promptly by expanding the lung. Even when opening the pleura is not followed by any untoward symptoms, the lung should be expanded by differential pressure anæsthesia just before the chest is closed.

WOUNDS OF THE HEART

The heart is rarely ruptured by concussion or compression of the chest. Even the thin walls of the auricles are very resistant to such force. Marias has reported, however, a patient who died the day following an injury to the chest with a superficial wound of the chest wall. Autopsy showed three linear lacerations opening into the right ventricle. Crushing injuries of the chest are fairly common and it is surprising that the heart and large vessels are so rarely lacerated by bone fragments.

Almost all of the wounds of the heart are due to penetration of the chest by missiles or by stab wounds. Following Rehn's report in 1896, there has been a gradually increasing list of suture of the heart following penetration of the heart muscle. Gunshot wounds of the heart are more serious than stab wounds. It is hard to say, from any reports available, just what percentage of patients with penetrating wounds of the heart live long enough to reach a hospital where operation may be performed. A large proportion of such patients die almost immediately or live less than an hour.

Ballance was able to collect only 58 cases report from the records of the great war. In the Bradshaw lectures delivered by him before the Royal College of Surgeons of England, December 11, 1919, the following statement was made:

" Pool's paper was published in 1912. Between that date and the Great War (August, 1914), there were more than 75 operations on the heart. The mortality of these operations has been slowly decreasing since 1896. I think that the death rate before the war may be put at about 45 per cent. Adding the cases during the Great War, which number over 60, we have a certain total of at least 380 operations on the heart. Since the performance of Farina's operation I have no doubt, however, that there have been many more than 400 operations on the heart to the present date. Many cases, especially the fatal ones, have not yet been published. Of 58 war cases of which I have notes 44 recovered and 14 died — a wonderful record! The French surgeons seem to have been very successful in these heart operations." In this same lecture a very excellent historical review covering the subject of Heart Wounds may be found.

The author was Chief of the Surgical Service of Evacuation Hospital No. 8, during the World War. We had a very active service from June 6, through to the Armistice and something over 12,000 wounded soldiers were admitted. I was on duty 12 hours in each 24 and did not recognize a stab wound of the heart during my tour of duty. Dr. H. O. Bruggeman was the Surgical Chief on the other 12 hour shift. He had one patient with a combined abdominal and thoracic injury with a slight wound of the ventricle near the apex which did not penetrate the heart. This man died of peritonitis.

Dr. Howard Lilienthal was the head of an operating team with us during the Argonne Offensive and did a great deal of the chest surgery. There did not come to his operating tables any penetrating wound of the heart.

The pathologist with the hospital was Dr. Roswell T. Pettit. A post-mortem was done on most of the fatal injuries and his records show no overlooked penetrating wound of the heart.

Dr. John L. Yates of Milwaukee, Wisconsin, was with Mobile Unit, No. 1, as Chest Surgeon and did a great deal of operating. The following statement is quoted from a letter from him dated January 17, 1930.

"In Volume XI, page 393 of the Surgeon General's Report of the World War occurs this statement:

'Early operations upon the heart and pericardium have been few because wounds affecting them are either promptly fatal or are treated expectantly. Such injuries as are disclosed by operation are easily remedied as they require little more than simple suturing.' Records of our work in France are no longer available. My memory is quite untrustworthy. I can recall not one heart muscle injury from a shell fragment that required suture and, I think, but two others in whom the pericardium alone was injured by projectiles. We saw not a single stab wound of heart or pericardium."

If a patient has a penetrating wound of the heart, the amount of hemorrhage will depend, to some extent, upon the size of the opening in the heart, but largely upon the size of the opening in the pericardium and how freely this opening communicates with the pleural cavity or with the outside. If the blood is retained in the pericardium a very moderate amount of hæmopericardium will very promptly bring about evidences of heart tamponade. These patients, when seen in the accident department, are usually in extremis; they are often unconscious, the heart sounds are faint and distant, the pulse at the wrist absent and the blood pressure may not register. They seem so nearly dead that opportunity for pericardiotomy and cardiorrhaphy may be lost, unless the physician on duty at the time is alert. If a patient with a penetrating wound of the heart lives long enough to be brought to a hospital there is usually time to get him to the operating room and begin operation before he succumbs.

The x-ray localization of a missile in the chest may be very difficult and if it is lodged in the lung close to the pericardium, determination of its exact position may be confusing. A foreign body that by x-ray examination is apparently in the pericardium, may move two or more inches away from its indicated position when the chest is opened and the lung collapses. In Lilienthal's Thoracic Surgery, volume ii, page 535, there is the following statement:

"We were occasionally embarrassed when metallic fragments were embedded in the lung by not finding them where they had been localized by the x-rays, because of collapse of the lung when air was admitted at operation. I conceived the idea of relocalizing these bodies on the admission of a quantity of air into the thorax through a trocar and cannula, before operation. In two cases in which we made use of this method the shadow of the foreign body had moved more than 3 inches. Manifestly, however, in open wounds of the chest in which pneumothorax is always present the usual methods of localization were all that were required. This method is of particular importance when a foreign body lies within the cardiac shadow, perhaps even moving with the heart's pulsations."

If there is no external bleeding many patients will survive the loss of blood needed to fill the pericardium and one pleural cavity provided the rate of bleeding is not rapid. If an auricle or large vessel near the base of the heart is opened, loss of blood is so fast that the rapid drop in blood pressure brings about a fatal syncope before blood in the peripheral vessels can reach the heart to make good the loss.

There may be surprisingly little hemorrhage outside of the pericardium and wounds of the heart may heal without being sutured. Aneurysms have been reported in the wall of the heart following healing without suture and in a number of cases these aneurysms had ruptured later.

Recently a patient was admitted through the accident department of the University Hospital, Baltimore, and operated on by the Resident Surgeon, Dr. C. F. Karns. This patient was a colored man aged 25, who was brought in after having been stabbed with a long stiletto. On admission his condition was very critical; the pulse was hardly perceptible and it was impossible to get his blood pressure. After giving him adrenalin and caffeine, however, his blood pressure rose to 30 systolic. Examination showed a laceration just below the left nipple, which, when probed, was found to go into the chest through the fifth intercostal space. It was believed that he had a stab wound of the heart.

He was immediately taken to the operating room and under general anæsthesia, the sterno-costal ends of the fourth and fifth ribs were excised and a portion of the left border of the sternum was also removed. A large slit in the left pleura and a laceration about an inch long in the pericardium were seen. The patient had a large hæmopneumothorax, the pericardium was bulging and about the size of a large grapefruit and was filled with blood, which was partially clotted. This was expressed after enlarging the pericardial incision and a stab wound of the left ventricle very close to the left auricle was found. This was a penetrating wound of the heart and large enough to admit the end of the index finger. With each movement of the heart a large stream of blood spurted out of the ventricle. An interrupted mattress suture was placed in the myocardium near the apex of the heart and using this as a traction suture, the laceration was closed with chromic catgut. Two Dakin tubes were fastened in the pericardial sac and the pericardium closed around these tubes. The pleural cavity was emptied of blood and the opening in the pleura sutured with fine chromic gut. The intercostal muscles were sutured and the incision in the subcutaneous tissue and skin closed snugly around the Dakin tubes which were brought to the outside.

The patient left the table in a very critical condition and did not improve much after operation, although his blood pressure rose to 90 systolic 36 hours later. Following this he developed numerous rales in both lungs and gradually became weaker despite all supportive measures and died three days after operation.

A post-mortem was done and the findings were: some cloudy swelling of the myocardium with a small area of fibrinous pericarditis. Both lungs were markedly congested. There was very little effusion on the left side and the left lung had fully expanded. These was no free blood, either in the pleura or pericardial sac. The stab wound in the heart which had been sutured was intact and there was no evidence of post-operative hemorrhage.

This patient might have had a better chance if the pericardium had been closed, leaving an opening large enough to allow blood to escape from it and the chest wall closed without drainage. In these cases infection is a serious post-operative menace.

CARDIORRHAPHY

In exposure of the injured heart for the arrest of bleeding, time is an important factor. Therefore, the different midline incisions are rarely used. Many different left-sided approaches have been reported in successful cases. Most of them fall in three groups: the Spangaro method, resection of cartilage and ribs, or trapdoor exposures.

While all of these methods give a rapid and satisfactory exposure, the long, intercostal Spangaro incision in the fourth or fifth interspace is growing in favor and this approach is much improved if the cartilages above and below the incision are separated from the sternum and a rib retractor used. The internal mammary vessels will usually require ligation.

In most instances the pleura will be found already injured, so that a larger opening in the pleura is made and the pericardium brought into view.

Sometimes the patient is unconscious and no anæsthesia is needed at the beginning of the operation. After the tamponade of the heart is relieved the patient may recover consciousness and begin to move. Some method of differential pressure anæsthesia should be at hand and gas, oxygen, ether is a satisfactory method. If the pleura is open and the heart is reached through this approach it may be necessary at any moment to expand the lung.

Even if the respiration goes on satisfactorily during operation with the left lung partially collapsed, differential pressure should be used at the end of the operation to expand the lung fully just before the chest is closed.

A good exposure of the heart is essential and a long incision should be made in the pericardium, which is usually full of blood. This should be removed and the next step determined by circumstance. If the opening is large and the heart bleeding furiously, either the procedure of Sauerbruch or Guinard may be used.

At the base of the heart the vena cava and the pulmonary veins enter the auricles on a plane posterior to the emergence of the aorta and pulmonary artery. The transverse sinus runs between these anterior arteries and posterior veins. Sauerbruch's method is to grasp the base of the heart with the left hand, placing the long middle finger through the sinus with the ring and little fingers behind the right auricle. Pressure of these fingers toward each other will shut off the flow into the right heart and the index finger and thumb may be used to steady the heart while the opening is sought for and closed. This should be done without much rotation of the heart and with as little lifting of the heart out of its bed as possible. There is no agreement as to just how long the blood coming into the heart may be shut off with safety; certainly not for very long. If compression is to be made, it had better be confined to compression of the vena cavæ and be intermittent.

Guinard's method enables one to grasp and steady the heart from above downward, but does not allow shutting off of the vena cava by pressure of the fingers. In this procedure the left hand of the operator reaches the heart from above and to the right. The thumb is placed on the anterior surface of the base of the ventricles and the middle and index fingers encircle the posterior surface of the heart. Or, almost the same maneuver may be used with the left hand approaching the heart from the right side and the heart grasped between the thumb and first finger in front and the other three fingers behind.

If the opening is a small one and the bleeding moderate, it is best not to grasp the heart at all. It is unwise to thrust a finger into the opening for fear of tearing it larger. Cutler advises, wherever possible, to place stay sutures through the apex of the heart and using these gently to steady the heart or to rotate it, place the tip of a finger over the opening in the heart muscle and control the bleeding temporarily in this way. A suture is then placed on either side of the finger into the heart muscle and these are gently pulled on in opposite directions across the hole. This will control bleeding and enable the accurate placing of sutures to close the opening. It allows more time, as the heart is not being compressed or lifted out of its bed. If the opening is in an auricle, it may be closed by a lateral ligature rather than suture. Lilienthal reports plugging an opening in the auricle with gauze followed by recovery.

The suture material may be either silk or catgut. Fine silk seems to be the safer suture and the needle should not be large enough to lacerate the muscle. Care should be taken not to try to steady the heart with the needle while suturing or to cut through the muscle by tying the sutures too tightly. All blood should be sucked or gently wiped from the pericardium and the parietal layer closed, but not too tightly, as enough room should be left between the sutures to allow escape of any fluid from the pericardial sac. The opening in the chest wall, however made, should be closed accurately and snugly without drainage. Vol. i. 930.

ARREST OF THE HEART

A distinction should be made between heart stoppage and heart failure. By heart failure is meant the act of "playing out" of the heart due to a number of causes: shock, hemorrhage, infection, long operation in a poor risk or a badly given anæsthetic. Such a failure may occur on the operating table or afterwards and it is usually next to useless to attempt to stimulate a heart that is gradually becoming weaker and weaker in its contractions, because of exhaustion. Treatment should be begun long before the heart failure reaches a serious stage.

By heart stoppage is meant the more or less sudden arrest of the heart during some operative procedure and not due to any of the above causes. Often the actual cause is uncertain and the accident may occur with dramatic suddenness in a patient, who apparently is an excellent risk and who, up to the moment of mishap, was in good condition.

Sometimes the actual arrest is preceded by some surgical handling, the pulling on the sac of a hernia, lifting up the stomach, etc. If the arrest occurs in the course of operation the question is up at once as to what part is played by the anæsthetic and often it is impossible to decide. If the difficulty is with the anæsthetic, usually there is a considerable period of respiratory difficulty before the heart is much affected and if the anæsthetist is able to bring about proper breathing the heart will take care of itself, but once in a while, the heart will be seriously disturbed and may suddenly stop. It is in this group of patients that a number of recoveries by heart massage have been reported after other and simpler means have failed. If such an accident occurs, the patient's head should be immediately lowered and the tongue pulled forward, the chest should be slapped sharply several times and artificial respiration begun. An intravenous injection of normal salt may be of benefit, but the injection of drugs into the peripheral circulation or into the subcutaneous tissues will be of little benefit, because there is no circulation of the blood. If, after a moment, the heart is still not beating, a small capillary needle attached to a hypodermic containing adrenalin should be thrust into the heart through the chest wall in the third or fourth interspace about 5 centimeters from the left border of the sternum and from 2–5 cc. of epinephrine (1/1000) injected. It is unwise to use a large needle for such injection and immediately after injection the capillary needle should be withdrawn.

The best procedure for bringing about cardiac contractions after heart stoppage is massage of the heart. This may be done through the diaphragm or through the chest wall. If the abdomen is already open, it is a comparatively easy matter to thrust the hand against the diaphragm and compress the heart between the fingers and the anterior chest wall. There is considerable difference of opinion as to how rapidly the heart should be massaged; some observers reporting a rate as low as 20, others as high as 60. This does not seem to be a matter of vital importance. The compression should be quick and sharp and enough time allowed for the ventricles to fill before another compression is made.

The time factor is a most important one. The heart muscle is quite resistant and a considerable number of reports show that the heart may begin contractions and continue to beat after it has been still for a considerable time, but if as much as ten minutes has elapsed between heart stoppage and the beginning of heart contractions, most patients will not recover consciousness and will ultimately die. It would seem that the brain is fatally damaged much more rapidly than the heart muscle and that while twenty minutes or more may elapse between heart stoppage and renewal of heart beat without serious damage to the heart muscle, ten minutes is about the outside limit that the central nervous system is able to withstand absence of blood and most observers believe that five to six minutes is a more correct margin of safety.

There are now available a number of reports dealing with this subject and Lockwood believes that ten minutes is about the limit, but Ricketts reports one patient in whom the heart had ceased to beat for twenty minutes. Bandaging of the limbs may be done, but is a procedure not without risk. There came into the University Hospital service about fifteen years ago, a young woman very nearly dead of concealed hemorrhage caused by rupture of an ectopic pregnancy. She was pulseless and unconscious and among other measures used to combat death from low blood pressure, bandaging of the limbs was done. She recovered, but has had ever since contractures of the calf muscles due to Ischæmic Palsy.

If neither the chest nor abdomen is open at the moment of heart stoppage, one has to decide quickly on the method of approach to the heart, either through the abdominal wall or through the chest. All things considered, it is probably a quicker and simpler procedure to hurriedly clean up the upper abdominal wall, make an incision in the midline from ensiform downward, long enough to admit the hand and grasp the heart by invaginating the diaphragm and begin massage, keeping up artificial respiration all the while.

If, for any reason, this approach is not feasible, then the chest should be opened by intercostal incision between the 4th and 5th ribs and the heart grasped and massage begun. Massage should be gentle and not too hurried; it is important to allow time enough for relaxation of the heart. If pulsations begin, the massage should be stopped and begun again only if pulsations become weak and irregular or cease altogether.

If the diaphragm cannot be invaginated sufficient to grasp the heart, then the heart may be rhythmically compressed between the hand and the anterior chest wall. If the diaphragm is not sufficiently relaxed to allow the operator's hand to reach the heart, an opening may be made in the diaphragm near the midline and close to the costal margin in front and the heart reached in this way. This is the transdiaphragmatic method.

There are then three methods of approach to the heart for massage: the subdiaphragmatic, the transdiaphragmatic and the intercostal. Because of the time factor, whatever is to be done must be done quickly and the upper abdominal approach has been used much more than the thoracic. It is hard to get enough room by an intercostal incision, unless the cartilages of two adjoining ribs are separated from the sternum and a rib retractor used.

MIGRATION OF FOREIGN BODIES

This is one of the most amazing collection of reports in surgery. All manner of foreign bodies have entered the heart, carried there by the circulation or have penetrated the heart directly and afterward been carried in the blood stream to distant vessels. A survey of the literature will show that bullets may travel almost anywhere in the circulation and in both directions, either toward the heart, in the veins or away from the heart in the arteries. Lockwood reported a large collection of such instances in the Archives of Surgery for January, 1929.

These foreign bodies make up an extensive collection: pieces of wood, needles, pieces of shell casing, shrapnel balls, bullets, nails, hairpins and pieces of bone. They may reach the heart in a number of ways: along the veins, from the œsophagus, from the lung or directly through the heart muscle.

While operating at Evacuation 8, stationed at Petit Moujouy in France, some time in October, 1918, Dr. George E. Alleman, the officer who was in charge of the x-ray Department in this hospital, sent a message to the operating room asking me to come into the dark room. There was a patient under the screen, who was being x-rayed for a penetrating wound just below the costal margin on the right side, which was discharging some bile. While examining the patient under the screen, Dr. Alleman noticed a small foreign body, evidently a piece of thin shell casing, lying in the neighborhood of the under surface of the liver and on palpation of the upper right abdomen this foreign body suddenly disappeared from under his eye and was almost immediately afterward located in the right side of the heart. When I saw it, it was revolving rather rapidly in the middle portion of the chest and very shortly afterwards, while being watched by Dr. Alleman, it disappeared from the neighborhood of the heart and lodged in the lung. This patient was seriously ill with peritonitis at the time of examination and was sent to the shock ward where he died a few hours after admission without being operated on.

DISPLACEMENTS OF THE HEART

The heart may be displaced either to the right or to the left. The more common of these displacements is dextrocardia, which is divided into congenital and acquired. Congenital dextrocardia is rarely a matter that concerns the surgeon in itself, but should be noted, of course, as it is evidence that other structures in the body may be transposed. It is with acquired displacements of the heart, either to the right or to the left, that the surgeon is concerned.

The simplest clinical method for determining these displacements is the finding of the apex beat out of its normal position. The point of maximum cardiac pulsation may be displaced far to the left or it may be displaced entirely into the right side of the thorax. This displacement to the left may be due to cardiac displacement or to hypertrophy and dilatation, but displacements of the apex to the right are usually due to dextrocardia. Etiologically, acquired dextrocardia may be divided into three groups, 1, those due to effusions into the left pleural cavity thereby pushing the heart toward the opposite side, 2, those due to fibrosis and contraction of the lung with adhesions between the parietal pericardium and the pleura pulling the heart to that side, and 3, massive collapse of the right lung. Ordinarily the heart lies in the chest, more or less under the midline of the sternum with about one-third of its mass extending to the right and two-thirds to the left of the midline and moderate degrees of cardiac displacement are common in many chest conditions, especially in tuberculosis. Writers on the subject of pulmonary tuberculosis have repeatedly called attention to the fact that in advanced cases it is exceptional to find the heart in a normal position. If the heart is pulled to the right by adhesions and contractions of the lung, the left lung will usually be found emphysematous and it may occupy a considerably larger area than normal.

It is quite possible that some pathology of the heart or pericardium may develop where there already exists some cardiac displacement. This displacement may be of sufficient grade to disturb the position of "the triangle of safety", or to interfere with the normal relationship of the heart and pericardium to the chest wall. It is, therefore, essential that the surgeon take these possibilities into consideration before attempting any operation, either upon the heart or upon the pericardium. This is especially true in pyopericardium complicating empyema, especially if the empyema is on the left side and the effusion a large one. If the heart is pushed far to the right, the uncovered area of the pericardium may be best reached by a right-sided approach.

THE SURGICAL TREATMENT OF CHRONIC VALVULAR DISEASE

Twelve patients have been operated on for stenosis of the openings within the heart. No effort has been made to repair a leaking valve. Ten of these were attempts at incising or excising the constricted margins of the valves and two were digital dilatations. Of the two dilatations, one was done by Tuffier by invaginating the finger into the aortic opening through the arterial wall without incision and the other was a finger dilatation of the mitral valve performed by Souttar through an opening in the left auricle followed by suture of this opening. This was done by a transpleural approach through an osteoplastic flap by turning back the second, third and fourth ribs. These two patients recovered and were reported improved.

Of the ten attempts at widening stenosis of intracardiac openings through incisions in the heart, nine were done for stenosis of the mitral valve and one for congenital pulmonary stenosis. The first patient operated on by Cutler lived four years and six months. The other nine died either of cardiac failure or pulmonary complications. Two lived six days and one three days. The other seven died in the first twenty-four hours.

In spite of the discouraging results, this group of cases presents a brilliant contribution to the records of surgical procedures. Doyen performed the first operation in 1913, for pulmonary stenosis. Tuffier's case was the second, already mentioned. Allen and Graham did the fourth case. Cutler, Levine and Beck did the third, fifth, sixth, seventh and eighth. Souttar, mentioned above, did the eighth. Pribram, the ninth and Cutler and Beck the eleventh and twelfth.

Previous to these a considerable amount of experimental operating had been done on the valves of the heart by physiologists and surgeons. Becker (1872), Klebs (1875), Colenheimer (1877), Tunofejew (1888) and Rosenbach (1899), concerned themselves with the study of the physiology of the circulation as affected by experimentally produced defects in the valves of the heart. These experimenters were not especially concerned with the life of the animal and were not attempting primarily to prove that the heart could be operated on with recovery.

It was the work of Cushing and Branch in 1907, and Bernheim in 1909, that established the fact that the valves of the heart and the openings they guard could be operated on without destroying the life of the animal. Allen and Graham beginning in 1922, and a little later Cutler, Levine and Beck published a series of reports of operative work on animals and humans for mitral stenosis. The reader is referred to the work of these two groups of investigators for a full discussion of this subject. Cutler and his associates have done most of the work in this field and have published a number of reports. This work was brought up to date in a paper published by Cutler and Beck in the Archives of Surgery for January, 1929. There is a full description by the same authors in Nelson's Loose Leaf Surgery, vol. 4.

SURGERY OF THE PULMONARY ARTERY

The pulmonary artery may concern the surgeon for several reasons. It is 1½–2 inches in length, comes off from the top of the right ventricle and is, throughout its course, within the pericardium. It lies to the left of the aorta and runs upward and backward. It divides into two main trunks, which enter the hilum of the right and left lungs respectively; the one on the right passing behind the ascending aorta and the left division passing in front of the descending aorta. The pulmonary artery and its bifurcation are below the arch of the aorta and the pericardium ascends high enough to allow ligature of either right or left pulmonary artery within the sac.

Because it is to the left of the aorta and high up in the chest, the pulmonary artery can be reached by a left-sided approach, keeping close to the margin of the sternum at the level of the second and third ribs. The pulmonary artery is thin and the pressure of the blood stream within it quite low as compared with the thickness of the aorta and the pressure within it.

There has been considerable discussion as to the practicability of ligation of the right or left pulmonary artery in the treatment of unilateral diseases of the lungs. Lilienthal reported intrapericardial ligation of the left pulmonary artery for extensive suppuration of that lung. The patient stood the operation well, but died soon afterward when he coughed up and aspirated a large quantity of pus.

Although I have seen no reference to it in the literature, there seems little reason why injury to the pulmonary artery might not be found in operating for the relief of heart tamponade due to hemorrhage in penetrating wounds of the pericardium. A small wound in the main artery might be found and sutured, as the artery is large enough to allow suture without occlusion and the pressure in the right side of the heart and great vessels is much lower than in the left.

The pulmonary artery is of chief interest, however, because of the increasing number of reports of successful operations for pulmonary embolism. This condition is a very sudden, unexpected and dramatic accident that may complicate trauma, infection or operation. Whether or not fat or air may cause serious blockage of the pulmonary arteries is not well known and there are few observations to guide us. The interruption to the blood stream is usually due to a blood clot, but it sometimes happens that the most painstaking search of the large vessels after death fails to discover any source from which the clot was detached.

Pulmonary embolism is apparently as common after simple, clean operative procedures without post-operative infection, as after very extensive operations, infections or trauma. Usually there is little preliminary warning and pulmonary embolism is a shocking and devastating accident. Not all of the patients die, however, and life may be sufficiently prolonged, even in the almost moribund cases, to allow of operation for the removal of the clot.

In the more serious cases there are a number of things that determine the question of life or death and the duration of life after the accident occurs. If the clot completely occludes both branches of the pulmonary artery, death is imminent and inevitable. Sometimes there is an alarming outset and some considerable improvement, followed at a varying interval by a second collapse, which is rapidly fatal. Autopsy in these cases has shown one branch of the pulmonary artery blocked and the proximal end of the clot extending around the bifurcations of the pulmonary artery into the other branch. At times, a second separate clot has been found and the supposition is that this second clot found its way into the pulmonary artery some time after the first embolus became lodged.

The modern study of this condition dates from the work of Virchow, about the middle of the last century. Cohnheim's great name is associated with pulmonary embolism and the work of Welch upon thrombosis and embolism is a landmark. Since then there has accumulated a very large literature devoted to these subjects, but it is with the practicability of surgical intervention in embolism of the pulmonary artery that this section is concerned.

There are many cases of pulmonary embolism where the clot is not a large one and lodges in a small branch. Sometimes these smaller emboli occur in showers. There is ample clinical and post-mortem evidence in proof of this. These patients have some cough, some discomfort in the chest, moderate fever and perhaps small areas with fleeting physical signs indicative of consolidation. The surgeon is uneasy, because of the fear of a larger embolism following the smaller ones, but the great majority of these patients recover without further mishap.

There is another group where the symptoms are more alarming, but these patients are not in extremis. They have a sudden pain in the side, are short of breath with some cyanosis and often spit up considerable bloody, frothy mucous. The heart is quickened and there may be evidence of right-sided dilatation. In a few hours a friction rub will usually be heard over the lung at the site of the pain and there will be x-ray and clinical evidence of an infarct of considerable size with its apex close to the hilum of the lung and its base covering a considerable area of the periphery of one lobe. These patients will usually recover, unless this embolism is followed later by a larger one or the clot backs up into the main trunk of the pulmonary artery. A later complication is infection of the infarct with localized pneumonitis followed by abscess of the lung.

It is with a third group that we are chiefly concerned here. These are the patients who develop most alarming symptoms of more or less complete blockage of the pulmonary artery. In most instances there is no opportunity to do anything worth while. Many of these patients will be dead by the time they are reached by the nurse or intern and even if the surgeon is at hand or the resident available, there is not time enough to begin any definitive operative relief. However, a number of these patients will continue to live for a few minutes and it is in this group that an increasing number of courageous attempts are being made to save life by opening the pulmonary artery and removing the clot.

There is a considerable literature upon the prevention of post-operative pulmonary embolism and many measures have been tried. One of the most pertinent suggestions is movement of the patient and exercise in bed soon after operation to prevent puddling of the blood in the veins. Heard has written a very full discussion of this phase of the subject. Many surgeons are fatalists as far as pulmonary embolism is concerned, because it is so often observed that patients who are doing well after a simple operation are stricken while the patient who has undergone a long and extensive operation escapes.

To many surgeons, operation for relief of this condition seems hedged about by so many difficulties as to make it very nearly outside the pale of practicable clinical surgery. But we have the reports of a number of men that, though the operation requires a well thought out method of attack, accurate knowledge of relationships and speed, there are no insurmountable difficulties. Lockwood says, " I have carried out the procedure repeatedly at autopsy. It is not at all a difficult feat."

Trendelenburg was the pioneer in this field and his method of exposure is still the one most used, although it has been modified in a number of

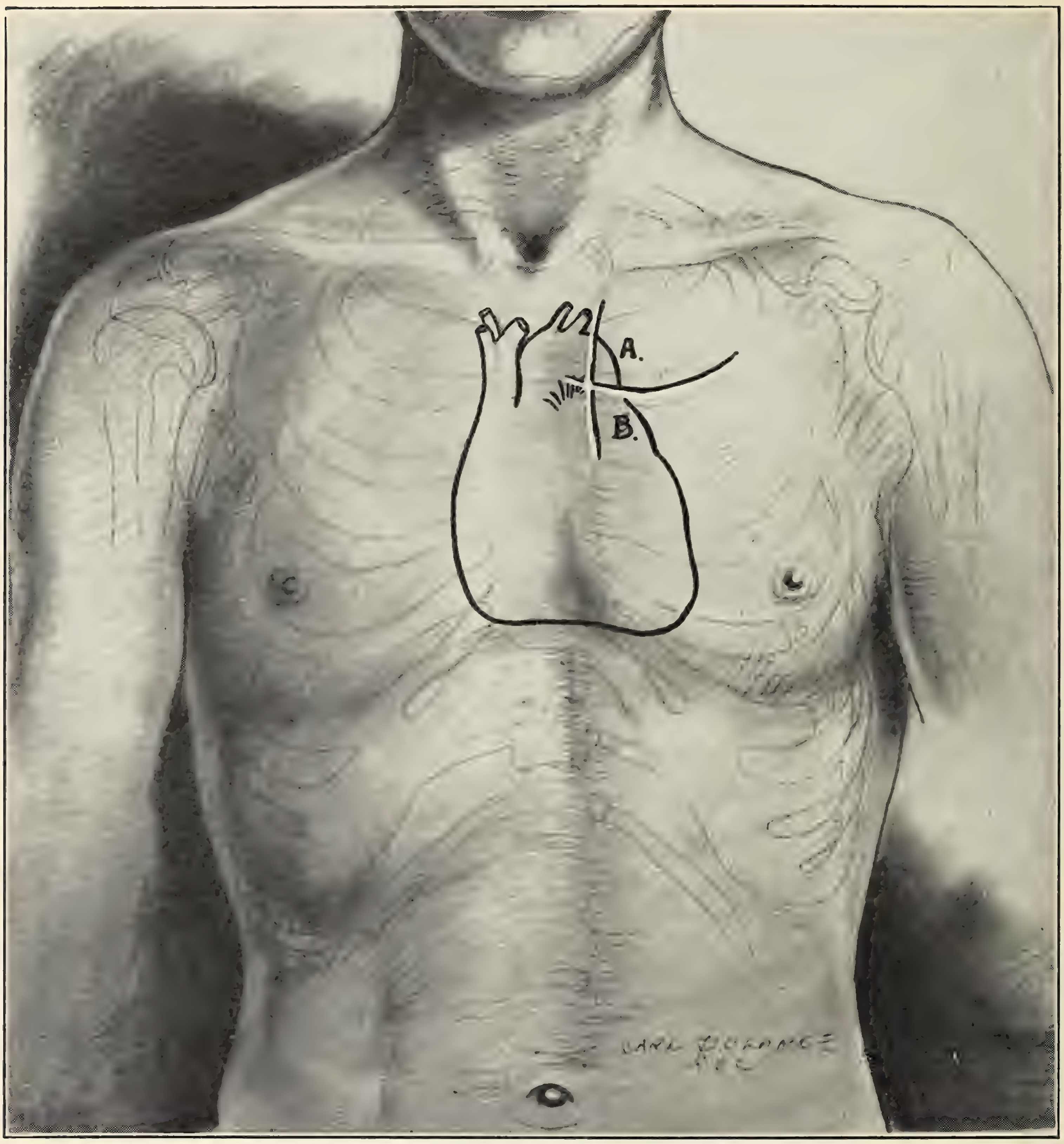

FIG. 15. Trendelenburg's Operation for Exposure of the Pulmonary Artery within the Pericardium.

The two triangular flaps are turned (A) upward and outward and (B) downward and outward and the inner ends of the second and third cartilages and ribs removed.

particulars. He and his assistants operated on twelve patients with no recoveries. Several of them lived long enough to establish the operation as a practicable procedure. He believed that fifty per cent. of these serious cases of pulmonary embolism had only one branch of the main artery blocked during the first hour and that in this relatively small group, operation offered a chance. Willy Meyer in 1913, gave an account of Trendelenburg's operative experience in this condition and discussed the surgery of the pulmonary artery.

The chief anxiety as to the wisdom of operation in any specific instance is created by lack of certainty as to whether a patient who is still living may not continue to improve. There is no way to be certain and a life may be lost at operation that might have recovered without.

If operation is to be undertaken, there are three great anxieties. The first is the paucity of time available for preparation. The second is the relatively short time that the aorta and pulmonary artery may be constricted while the artery is being opened, the clot removed and the artery closed. The third is the actual incision and closure of the pulmonary artery, as blood cannot be too freely lost and blood obscures the operative field.

The avenue of approach as used by Trendelenburg is a " T " incision with one arm through the skin parallel to the left of the sternum from the first rib to the third, and the other arm of the T carried out along the second cartilage and rib for 10–12 centimeters. Two triangular flaps down to cartilage and ribs are dissected free, one outward and upward and the other outward and downward. The second rib and cartilage are excised for the full length of the incision and a shorter length of the third rib and cartilage removed also. The internal mammary vessels are either pushed toward the midline or tied. The pleura is incised and retracted. The collapse of the lung exposes the pericardium. The vessels at the base can be felt through the pericardium, the phrenic nerve is pushed to the left and the pericardium incised. This will bring the pulmonary artery and aorta directly into view with the pulmonary artery to the left of the aorta. The next problem is to devise some means of controlling hemorrhage during the time the artery is open and the clot is being sought and removed. The pericardial sinus is of great use here. The aorta and pulmonary artery come off from the top of the ventricles and between the beginnings of these great vessels and the auricles behind them, is the pericardial sinus through which an instrument may be passed from left to right and a rubber tube drawn in the opposite direction, which can be used to occlude the aorta and pulmonary artery while the latter vessel is open.

This tube may be held by an assistant, who uses it to elevate the heart, to steady it and to compress the aorta and pulmonary artery at about the level of their valves. When everything is ready the rubber tube is tightened and a short incision made in the pulmonary artery. A curved, blunt forceps is introduced into the lumen and the clot sought. A number of operators have noted that the clot could not be located by palpation before opening the vessel and it may not be immediately located, as it may be in either branch. Very little time is available, as it is agreed that the pulmonary artery can be safely occluded only from 45 to 90 seconds.

After removal of the clot, closure of the opening in the vessel is made by turning out the edges of the incision and closing it with fine silk. Trendelenburg devised a two blade pick-up forceps with the teeth turned outward, so that the edges of the vessel could be engaged, elevated and approximated while the sutures were being applied. A number of methods have been used for controlling hemorrhage during the placing of the sutures. The artery is large enough to allow suturing without seriously interfering with the lumen.

Other approaches than the original one devised by Trendelenburg have been used. Two ribs are resected in the original operation. This takes time and makes an air-tight closure difficult. Lake removed a portion of the sternum with Rongeur forceps.

A Spangaro approach between the second and third ribs, cutting the second and third ribs from the sternum and using a rib retractor should give a quick and adequate exposure. A rubber guarded clamp may be used with one blade passed through the pericardial sinus and the anterior blade in front of the great vessels, instead of the rubber tubing mentioned above. This clamp can be tightened and loosened as occasion demands. If the index finger of the left hand can be passed from right to left through the pericardial sinus and the beginning of the pulmonary artery grasped between the finger behind and thumb in front, it would give a very mobile means of controlling hemorrhage while the artery is open. It would allow the operator to steady the heart and pull it forward with his left hand, but would leave him only one hand with which to close the incision in the artery.

Kirschner was the first to report successful operation for embolus of the pulmonary artery. He followed the Trendelenburg method and opened the left pleural cavity before incising the pericardium.

Most of the surgeons who have reported their experience with this operation since then, condemn this part of the Trendelenburg procedure and lay stress on entering the pericardium without opening the pleura.

Meyer reported a successful case in September, 1928. This patient had been operated on nine days before the pulmonary accident for ruptured ovarian tumor. She did well until symptoms of pulmonary embolism developed and gradually grew worse until embolectomy was decided upon. The Trendelenburg operation was modified by removing a portion of the third rib and stripping back the pleura without opening it.

Meyer also used a smaller model of the Trendelenburg sound in passing the tourniquet behind the aorta and pulmonary artery. He practiced intermittent compression of the great vessels and digital slit compression between the attempts at removal of the clots from the pulmonary artery. He has reported two other successful cases.

Stegemann reported a successful operation for pulmonary embolism together with observations made over a period of four years after operation. During this time the patient showed no edema, cyanosis or palpitation and apparently was entirely well. Clinical roentgenological and electrocardiographic examination of the heart and lungs showed no pathological findings.

The patient was a woman 38 years old, who had been operated on for irreducible fracture of the femur. Three days after operation she developed massive pulmonary embolism and the Trendelenburg operation was performed March 18, 1924.

The patient was moribund and was operated on without anæsthetic. There was no bleeding. The heart ceased beating while the large vessels were shut off and showed only some fibrillary quiver. This period of occlusion of the vessels lasted from 40–50 seconds. He followed the Trendelenburg approach and, as stated above, this patient recovered.

Crafoord reported two recoveries after removal of clot from the pulmonary artery. He did not open the left pleura before incising the pericardium and believes that the injection of adrenalin into the aorta near the base of the heart and into the heart is an important aid in promoting heart contractions. Crafoord observed that there is little bleeding when the artery is opened, as the circulation is almost at a standstill and that the chief need for the tourniquet is to pull the vessels gently forward and steady them while the pulmonary artery is being operated on.

Nystrom reported three patients operated on for embolism of the pulmonary artery. All three left the operating table alive; a woman, aged 48, whose original operation was for hemorrhoids, lived thirty hours; a woman, 45 years old, who had had a cholecystectomy done, lived five hours. The third patient, a man aged 35, (pulmonary embolism after appendectomy), recovered and resumed his occupation.

In the first case a typical Trendelenburg operation was done, but in the other two the pericardium was incised without opening the pleura.

In one case small rupture of the intima of the pulmonary artery was found, caused by pulling on the tourniquet.

In case 1, the blood stream was cut off sixty seconds, in case 2, sixty-five seconds and in case 3, the patient who recovered, one hundred and four seconds. In this last case the clot was removed largely with the aid of suction.

De Harven operated on three patients with pulmonary embolism, but all three died on the operating table. This operator observed that the clot in each instance lay free in the pulmonary artery without any adhesions to the vessel wall.

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